LBNL-6470E

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Automated Demand Response Technologies and Demonstration in New York City using OpenADR

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September 2013

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Prepared for

THE NEW YORK STATE
ENERGY RESEARCH AND DEVELOPMENT AUTHORITY
Albany, NY

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NYSERDA Agreement No. 20723

September 2013

Notice

Disclaimer

Acknowledgements

The work described in this report was coordinated by the Lawrence Berkeley National Laboratory and funded by the New York State Energy Research and Development Authority under the Agreement No. 20723. This work was sponsored in part by the Demand Response Research Center which is funded by the California Energy Commission (Energy Commission), Public Interest Energy Research (PIER) Program, under Work for Others Contract No. 500-03-026 and by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Abstract

Demand response (DR) – allowing customers to respond to reliability requests and market prices by changing electricity use from their normal consumption pattern – continues to be seen as an attractive means of demand-side management and a fundamental smart-grid improvement that links supply and demand. Since October 2011, the Demand Response Research Center at Lawrence Berkeley National Laboratory and New York State Energy Research and Development Authority have conducted a demonstration project enabling Automated Demand Response (Auto-DR) in large commercial buildings located in New York City using Open Automated Demand Response (OpenADR) communication protocols. In particular, this project focuses on demonstrating how OpenADR can automate and simplify interactions between buildings and various stakeholders in New York State including the independent system operator, utilities, retail energy providers, and curtailment service providers. In this paper, we present methods to automate control strategies via building management systems to provide event-driven demand response, price response and demand management based on OpenADR signals. We also present cost control opportunities under day-ahead hourly pricing for large customers and Auto-DR control strategies developed for demonstration buildings. Lastly, we discuss the communication architecture and Auto-DR system designed for the demonstration project to automate price response and DR participation.

Keywords: commercial building, demand response, dynamic pricing, mandatory hourly pricing, OpenADR, Open Automated Demand Response, price response, smart grid

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Summary

Since October 2011, the Demand Response Research Center (DRRC) at Lawrence Berkeley National Laboratory (LBNL) and New York State Energy Research and Development Authority (NYSERDA) have conducted a demonstration project enabling automated demand response (Auto-DR) in large commercial buildings located in New York City (NYC) using Open Automated Demand Response (OpenADR). This interim report details the overall project concept, objective and progress. Currently, Auto-DR functionality has been commissioned at some demonstration sites and project's time line has all sites being commissioned, tested and operational over the summer and fall of 2013.

OpenADR is an open and interoperable communication standard that facilitates smart-grid information exchange among various entities such as utilities, system operators, aggregators, energy services providers, and end-users. These interactions are defined as client-server transactions via Internet using XML (eXtensible Markup Language) data models. OpenADR is different than other demand response application protocols, like Smart Energy Profile (SEP) intended for home-based device interactions over advanced metering infrastructure (AMI) based transport. OpenADR messages are used to communicate demand response (DR) requests, energy pricing and schedules from servers (e.g., utilities, system operators, energy suppliers, etc.) to subscribing clients at customer sites. As an open specification, OpenADR can simplify the implementation of multiple signaling systems and ease the adoption of building automation. As a machine-to-machine standard, OpenADR can interact with buildings and industrial control systems that are preprogrammed to take action based on DR or price signals in a fully automated fashion with no manual intervention. As a result, the demand-side resources can be used more frequently in smart grid transactions contributing to grid reliability and robustness.

New York State's (NYS's) market structure provides several mechanisms intended to encourage larger customers to reduce their impact on the grid. These include hourly prices for energy constraints; retail demand tariffs and utility DR programs for distribution system constraints; wholesale DR for capacity constraints; and even dispatchable DR for providing Ancillary Service to the New York Independent System Operator (NYISO). OpenADR supports all of the common NYISO, utility, retail energy provider (REP) and curtailment service provider (CPS) interactions with commercial customers in NYS. Individually, these interactions are not complicated. However, as the number of interactions increases, the customer's burden to respond to multiple interactions also increases. OpenADR can simplify this process by standardizing how each will present its signals in a standards-based machine readable format and making it easier for more buildings to respond in ways for the benefit of a smarter gird in NYS.

The project focuses on following:

1) demonstrate how OpenADR can automate and simplify interactions between buildings and various stakeholders in NYS including the NYISO, utilities, REPs, and CSPs;
2) automate building control systems to provide event-driven demand response, price response, and demand management according to OpenADR signals; and
3) provide cost-saving solutions to large customers by actively managing day-ahead hourly prices and demand charges.

<u>Event-Driven Demand Response</u>

Using OpenADR, the NYISO or utilities could publish DR event notifications including the program type, date, time, and duration as well as target type (by load zone, geographic location, or program associations). Based on the DR event information published by the NYISO or utilities, a CSP can use OpenADR to communicate a DR event to all or selected groups of program participants. A participating building can subscribe to their CSP's OpenADR signal to receive DR event information. Upon the receipt of OpenADR signals, sites can respond automatically, manually, or a combination of both. If the response is automated, OpenADR signals would trigger pre-programmed control strategies via the facility's building management system (BMS). A BMS system could also guide facility operators to manually change operations and control set points.

Price Response

The NYISO could publish wholesale (i.e. Day-ahead Locational Based Marginal Price) prices in OpenADR protocol. Utilities and REPs can receive price signals from the NYISO and determine their rates (minus adjustments) to reflect the wholesale market variations. End-users who respond to dynamic pricing can pull the OpenADR price information from a utility, a REP or the ISO via their OpenADR client and manage energy consumption accordingly. The buildings could dynamically control and optimize loads to minimize costs according to the day-ahead price variations. If the buildings do not have the ability to process the dynamic price information and make decisions about how to respond to that information, the OpenADR server can generate simple operation mode (*Normal*, *Moderate*, *High*, or *Special*) for the buildings based on the price information. The buildings can then trigger pre-programmed control strategies based on the simple operation mode.

Demand Management

In NYS, customers pay delivery charges that are largely based on the maximum demand of each billing cycle to reflect the cost of the distribution infrastructure. Typically, the delivery charges for large customers are more expensive in summer than winter and additional charges apply during peak hours. Therefore, it is important that the customers manage their maximum demand in order to reduce electricity bills. The OpenADR server can assist the building's peak load management by monitoring electric demand in real time and automate peak load reduction if the demand is nearing a preset threshold.

Auto-DR Demonstration in NYC

Four buildings were recruited for the demonstration project. Preferences were given to the buildings that represented the typical construction of large commercial buildings in NYC. All demonstration buildings previously participated in one or more incentive-based DR programs through CSPs. Prior to this project, the load reduction at these buildings was provided through manual control of HVAC, lighting, and other systems.

OpenADR Communication Architecture

Currently in NYS, wholesale day-ahead hourly prices are published in a downloadable spreadsheet format at the NYISO website and are made available from some utility websites. Today, DR event notifications are propagated via email and phone by the NYISO and CSPs. Since the NYISO, Consolidated Edison (Con Edison), and CSPs did not publish price or DR signals using the OpenADR protocol, the project team used a centralized server to mimic the transfer of these signals from these entities to the facilities using OpenADR data models. Con Edison's customers who are subject to the default Mandatory Hourly Pricing (MHP) tariff are billed under Rider M for their electricity supply. Under this rider, the cost of energy is roughly calculated based on the customer's actual hourly energy usage multiplied by the NYISO's day-ahead zonal locational based marginal price (DA LBMP). This does not account for miscellaneous charges like taxes and adjustments which do not vary hourly. To generate a standards-based machine readable pricing signals, the project's OpenADR server scrapes DA LBMP published on the NYISO's website and converts the data into OpenADR data models for each day.

For this project, DR event notifications undergo a similar conversion to machine-readable OpenADR protocol. If a CSP sends DR test/event notifications to the customer via email, the OpenADR server would receive the same email and convert the message into OpenADR signals. The customer's building automation is equipped with OpenADR client software that reads both the OpenADR signals for daily prices, day-ahead DR event notifications, and day-of DR notifications. The facility's BMS activates respective pre-programmed control strategies. The OpenADR server also collects electric meter data for monitoring purposes. All information exchange is accomplished through a secure Internet connection with 128-bit Secure Sockets Layer encryption.

Building Auto-DR System Design and Configuration

A site's Auto-DR system design and configuration depends heavily on the capabilities of existing building control systems and protocols. It is common for large commercial buildings to have several systems and devices (i.e., HVAC, lighting, electric, security, etc.) used for building operation. A centralized BMS integrates individual control systems/devices to provide greater controllability and efficiency to building managers. Installing a centralized BMS can be a seamless process if all systems/devices use an open building automation communication protocol (i.e. BacNet, Modbus, Lonworks, etc.), which facilitates interoperability between different vendors' systems. Open building automation communication protocols are a vendor-neutral standard used within a facility supporting all building systems and devices equally. (OpenADR, on the other hand, is a smart grid data protocol developed to facilitate interoperable exchange of information relating to electricity market information, transactions, etc.) The use of an open building automation communication protocol is advantageous for Auto-DR when multiple systems/devices need to respond to the same OpenADR signals. Three of the four demonstration sites' BMS use BACnet as the building automation communication protocol and one building uses a proprietary protocol.

<u>Auto-DR Equipment Installation and Programming</u>

Each demonstration building had a vendor-specific BMS, namely Honeywell's Enterprise Buildings Integrator, Automated Logic Corporation's WebCTRL®, Schneider Electric's Andover Continuum, and Johnson Control Inc.'s Legacy respectively. Honeywell provided the overall system design and equipment installations for the project. Programming of the Auto-DR control strategies was done by subcontractors who can program in each vendor's software. Most of the control strategies were HVAC-related, such as set-point changes and fan speed reduction. We proposed lighting strategies for two buildings in addition to the HVAC strategies. However, the lighting system was not integrated into the BMS prior to the project and additions would increase costs and further delay the project.

Conclusions and Next Steps

In this report, we provided progress updates on project by presenting customer bill control opportunities, Auto-DR implementation methods, and DR control strategies for the project's demonstration buildings. The demonstration buildings were automated to provide event-driven demand response, price response, and demand management according to OpenADR signals. Control strategies were designed to curtail customer's load as per day-ahead hourly prices and demand charges as well as DR events. HVAC control strategies were often the first to be automated because they were effective at lowering demand and they could be easily controlled through the facility's BMS. The strategies involving starting chillers during non-operational hours (i.e., precooling) could not be automated because they require a site engineer to be present by the NYC Fire Code. The implementation of Auto-DR system in demonstration buildings heavily depended on the existing control systems and communication protocols. The building systems that used an open building automation communication protocol were easier to automate than the ones used proprietary protocols because the open protocols could speak to multiple systems/devices manufactured by different vendors to activate control strategies according to OpenADR signals.

To this point, we concluded that 1) OpenADR can support the price and DR interactions defined by the deregulated and restructured market in NYS; 2) price response to day-ahead hourly pricing can be made easier through Auto-DR; and 3) Auto-DR helps customer's DR participation by eliminating human labor and costs to provide DR and making it a repeatable and error-free process.

Auto DR enablement and commissioning at all sites were completed in early summer 2013. The DR testing has taken place throughout the summer and fall of 2013.

1 Introduction

Demand response (DR) – allowing customers to respond to reliability requests and market prices by changing electricity use from their normal consumption pattern – continues to be seen as an attractive means of demand-side management and a fundamental smart-grid improvement that links supply and demand. Large customers are often the first and most cost effective target for DR because they are major contributors to peak demand for electricity and they are equipped with centralized building management system (BMS). With increased adoption of interval meters, standards-based building control networking, and building automation systems, an enormous opportunity lies ahead for medium and large customers to exercise their full DR potential. However, today most adjustments to building controls and operations are done manually, making responding to more frequent reliability events, hourly price response and daily peak shaving impractical. Customers' ability to perform DR can significantly improve by enabling automated demand response (Auto-DR) [1]. By reducing the need for humans-in-the-loop, Auto-DR can reduce the operational burden to provide real-time response and lower the cost associated with monitoring and responding. It also helps customers leverage the flexibility of their buildings by automating responses to price and reliability signals. Therefore, Auto-DR can help make the grid more sustainable and cost-effective.

Since October 2011, the Demand Response Research Center (DRRC) at LBNL and New York State Energy Research and Development Authority (NYSERDA) have conducted a demonstration project enabling automated demand response (Auto-DR) in large commercial buildings located in New York City (NYC) using OpenADR. New York State's (NYS's) market structure provides several mechanisms intended to encourage larger customers to reduce their impact on the grid. These include hourly prices for energy constraints; retail demand tariffs and utility DR programs for distribution system constraints; wholesale DR for capacity constraints; and even dispatchable DR for providing Ancillary Service to the New York Independent System Operator (NYISO).

The project focuses on following:

1) demonstrate how OpenADR can automate and simplify interactions between buildings and various stakeholders in NYS including the NYISO, utilities, retail energy providers (REPs), and curtailment service providers (CSPs);
2) automate building control systems to provide event-driven demand response, price response, and demand management according to OpenADR signals; and
3) provide cost-saving solutions to large customers by actively managing day-ahead hourly prices and demand charges.

The rest of the report is organized as follows. In Chapter 2, we provide an overview of DR programs in NYS's wholesale electricity markets and discuss cost control opportunities under day-ahead hourly pricing. In Chapter 3, we explain some of the key concepts of OpenADR specifications and describe how OpenADR can assist smart-grid interactions between the stakeholders in NYS. In Chapter 4, we describe general methods used for Auto-DR implementation in large commercial buildings in NYC. In Chapter 5, we describe the specific demonstration buildings and DR strategies developed for each participating building. Lastly, we summarize the key findings in Chapter 6 and suggest future research opportunities in Chapter 7.

2 Background

Prior to the project implementation, the DRRC commissioned an overview study of the wholesale and retail electricity markets in NYS; the types of DR programs; retail pricing structures; and Mandatory Hourly Pricing (MHP) [2, 3]. In this chapter, we summarize the findings from this study and discuss cost control opportunities under the day-ahead hourly pricing. The demonstration sites for this project are in Manhattan and therefore in Con Edison's service territory.

2.1 Demand Response Forms Currently Present in New York State

The NYISO administers several DR market programs aligned to the following wholesale markets:

- Capacity (installed capacity);
- Energy (day-ahead balancing auctions); and
- Ancillary services (regulation, spinning reserve and non-spinning reserve).

Additionally, utilities offer out-of-market DR programs to address their own transmission- and distribution-level constraints and emergencies.

There are four generic forms of demand response present in NYS: 1) facility peak-shaving; 2) utility direct load control, 3) reliability DR programs (curtailment and distributed generation) and 4) dynamic pricing. Direct load control in NYS is a Con Edison program specific to small customers and is therefore not examined in this project, but this project will examine Auto-DR as a means of facilitating the other three. In NYS, several incentive-based reliability programs are offered by the NYISO and utilities. Table 1 lists the name, service type, and trigger mechanism of all incentive-based programs currently available in NYC.

Table 1. Demand response curtailment programs in New York City

Program Name	Operator	Service Type	Trigger
1. Installed Capacity Special Case Resources (SCR)	NYISO	Capacity	Reliability
2. Emergency Demand Response Program (EDRP)	NYISO	Energy	Reliability
3. Commercial System Relief Program (CSRP) (aka Peak)	Con Edison	Out-of-market	Reliability
4. Distribution Load Relief Program (DLRP) (aka Contingency)	Con Edison	Out-of-market	Reliability
5. Day-Ahead Demand Response Program (DADRP)	NYISO	Energy, Reserve and Regulation	Market bid/dispatch

Customers are compensated for committing to reduce their electricity use during DR events by receiving seasonal reservation payments based on market prices and tariffs respectively. Customers typically participate in curtailment programs through CSPs. CSPs manage a portfolio of DR resources and their response during DR events as well as aggregating smaller resources.

Dynamic pricing communicates variations in wholesale prices that may induce changes in customers' energy consumption behavior in addition to the utility tariff components such as demand/delivery charges which are not dynamic but also may induce peak shaving. Dynamic pricing exists as an optional or mandatory utility tariff, or retail third-party energy supplier contract. In NYS, MHP is the default utility service tariff for electricity for large commercial and industrial customers which indexes energy supply to wholesale market prices[1].

[1] MHP was mandated as part of the decision made by the State of New York Public Service Commission in 2005 [4].

2.2 Barriers to Hourly Price Response in NYS

Although utilities offer MHP as the default service to large customers, NYS's retail access policy allow customers to purchase their energy from any retail third party supplier with various pricing structure as an alternative to the utility so MHP is not strictly 'mandatory'. In practice it is widely understood that NYS customers for whom MHP may apply (roughly over 500kW demand) typically contract with a REP and choose energy pricing that is not dynamic. The form of these retail supply contracts are not regulated and often are flat-price contracts. REPs represent their customers in the wholesale market as load serving entities (LSEs) for the purchase of forward capacity, forward and scheduled energy and ancillary services. This structure is intended to equitably allocate wholesale costs to customers and provide sufficient forward signals to the capacity and energy markets.

As of 2011, only 15% of the MHP-eligible customers were enrolled in MHP and the rest (85%) were retail access customers [5]. Anecdotally, it is thought that flat price contracts are compelling for customer to contract with a REP. The problem of this trend is that flat price retail contracts hedge against price fluctuations and therefore do a poor job of reflecting wholesale near-term market prices (day-ahead, hour-ahead and real-time). Flat price contracts are more expensive due to the inherent risk premium of offering a less variable rate [6]. When retail prices are not tied to wholesale market variations, they can "inefficiently increase the level of peak demand by underpricing" electricity and can also "discourage increased demand during off-peak hours by overpricing it" [9]. The net effect is inefficiency and added costs in the near term energy markets. NYS customers are allowed to pay a premium for the security of a flat rate, but the premium does not cover the added costs to other customers having to absorb higher energy prices (LBMPs). Thought retail products with dynamic prices indexed to the near-term wholesale energy prices exist, there is no method for making day-ahead prices broadly available.

The recent report by KEMA identified the primary barriers to the adoption of MHP and indexed retail contracts as insufficient resources to monitor hourly prices and inflexible labor schedule [5]. This is not surprising since most customers rely on manually adjusting their systems and operations to provide DR. Providing DR manually is a labor-intensive process. If customers do not have the capability to monitor daily or hourly price variations and manage their loads in an automated way, they are likely to choose a more conventional rate such as a flat rate. It should be noted that customers often prefer stable energy prices for budgeting purposes. Moreover, customers have not yet found a compelling business case to stay with MHP or choose indexed retail products. Many customers presume that the cost of monitoring and automation outweighs the potential savings. Even if the savings exist under day-ahead hourly prices, they are not as obvious and repeatable as the DR payments because the savings are a function of the market and are embedded in the total electricity bill. Therefore, in order to increase the adoption of MHP and dynamic-price retail contracts, we not only need to make the prices broadly available but also automate customers' price response. Moreover, potential savings and ways to achieve it should be clearly communicated to customers.

2.3 Cost Control Opportunities

<u>Day-Ahead Hourly Price Management</u>

Customers' electricity bills are made up of a number of different charges but they can be generalized into three large categories: supply, delivery, and miscellaneous charges. MHP is used to calculate the supply portion of electricity bills for large commercial customers unless the customer purchases electricity from a retail energy supplier. Con Edison's customers who are subject to the default MHP tariff are billed under Rider M for their electricity supply. Under this rider, the cost of energy is calculated based on the customer's actual hourly energy usage multiplied by the NYISO's day-ahead zonal locational based marginal price (DA LBMP) [7]. The price variation in DA LBMP is perceived by customers to be wide and unpredictable. Although a market is inherently unpredictable, our analysis over a year ending August 2012 revealed a different story: 1) DA LBMP stayed within a narrow range most of the time and 2) spikes in DA LBMP were concentrated on cooling and heating dominated hours. Following figures support our findings. Figure 1 displays the price duration curves of DA LBMP for Zone J: NYC between September 2011 and August 2012 [8].

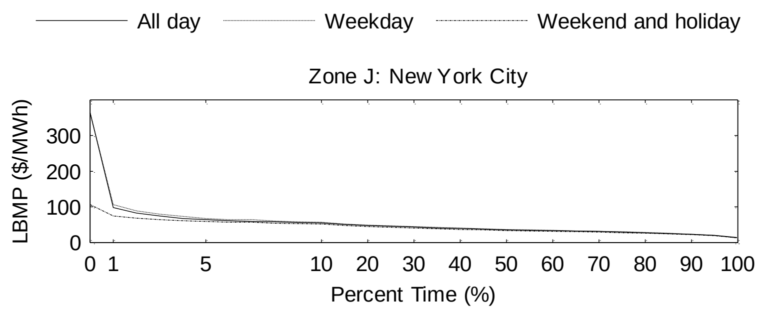

Figure 1. Price duration curves: New York City LBMP from Sept 2011 to Aug 2012

DA LBMP did not vary significantly between weekdays and weekend/holiday. The price mostly stayed below $100 per MWh. Deviation from that was only seen during the top one percent of the hours where the price increased up to $363 per MWh. When plotted against the time of day, as shown in Figure 2, it was clear that the prices corresponding to the top one percent of the hours were concentrated around cooling season (summer afternoon) and heating season (winter morning and evening).

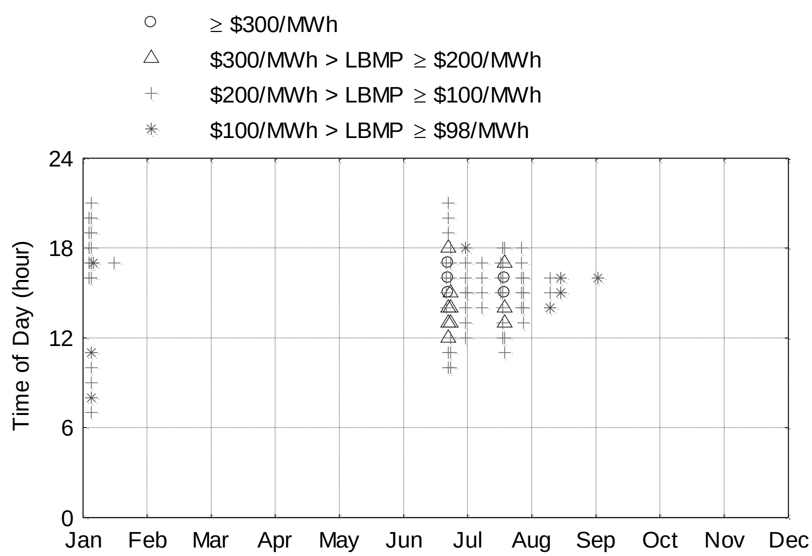

Figure 2. Distribution of New York City LBMP over month and time-of-day during the top 1% of the time between Sept 2011 and Aug 2012

Therefore, controlling loads during the top one percent of the time, over the period we analyzed, would have helped customers reduce their electricity bills were they on MHP. The same would be true for retail customers whose electricity prices were tied to wholesale market variations. Moreover, reductions in demand during peak hours by large customers can increase the efficiency of markets and reduce generating costs in the long run [9, 10].

Demand Management

In addition to supply charges, large customers under Con Edison's Service Classification 9 (SC-9) or those with a retail energy supplier pay delivery charges to utilities for the delivery of electricity [11]. Table 2 shows the table of Con Edison's delivery charges under SC-9, Rate II – Time-of-Day applied to customers whose monthly maximum demand exceeds 1,500 kW.

Table 2. Con Edison SC-9 - General Large, Rate II - Time-of-Day Delivery Charges[2]

Component of Delivery Charges	Charges/Units
Demand Delivery Charges	
Summer, all days, all hours	$16.62 / kW-max demand
Summer, weekday, 8am-6pm (additive)	$8.28 / kW-max demand
Summer, weekday, 8am-10pm (additive)	$15.49 / kW-max demand
Winter, all days, all hours	$5.33 / kW-max demand
Winter, weekday, 8am-10pm (additive)	$11.42 / kW-max demand
Energy Delivery Charges	
All months, all days, all hours	0.82¢ / kWh
Other Charges	
Metering Services	$/month
Reactive Power Demand Charge	$/kVar
Additional Delivery Charges and Adjustments	varies

The delivery charges have two main components: demand delivery and energy delivery. The demand delivery charges have a tiered pricing structure calculated based on the maximum demand of each billing cycle. The demand delivery charge is more expensive in summer than winter and additional charges apply during peak hours. Hence, customers need to reduce energy demand during expensive periods in order to save electricity bills. The energy delivery charge is a flat fee charged based on the total consumption of the billing cycle; therefore, customers are not penalized for one-time peak demand for this charge. Additional charges such as metering, reactive power, and payment processing fees are applied to include the cost of the distribution infrastructure that the utility must maintain.

<u>*Sample Case*</u>

A sample breakdown of customer's electricity bills is shown in Figure 3 and Figure 4. Figure 3 was developed based on the actual monthly electricity bills in 2011 collected from one of our demonstration buildings that purchased electricity from and is billed by the New York Power Authority (NYPA). NYPA applies Time-of-Day (TOD) rates to calculate the supply portion of electricity bills. Using the customer's interval meter data from 2011, we created shadow bills as if this customer had taken service and had been billed by Con Edison in 2011 under the MHP tariff (SC-9 with Rider M) shown in Figure 4. The numbers are shown in percentage where 100% represents the total annual electricity cost in 2011. The charges are grouped by seasons and the type of charges.

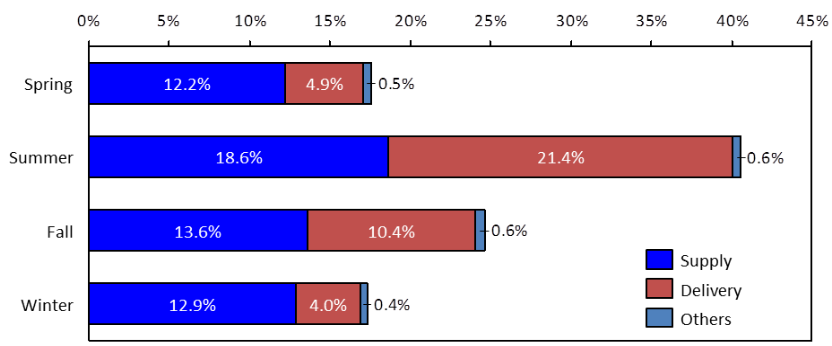

Figure 3. NYPA: actual electricity bill breakdown for a sample office building in 2011[3]

[2] effective as of 04/01/2012, available at http://www.coned.com/documents/elecPSC10/SCs.pdf

[3] Spring includes March, April, and May. Summer includes June, July, and August. Fall includes September, October, and November. Winter includes December, January, and February.

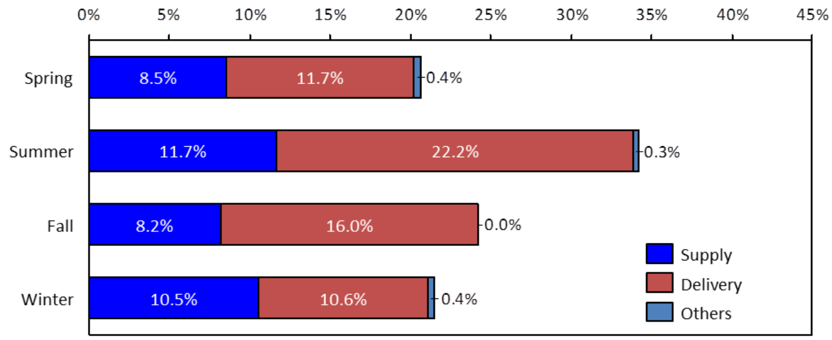

Figure 4. Con Edison: predicted electricity bill breakdown for a sample office building in 2011

Some of the key observations are summarized below.

- Despite of the concerns of being subject to hourly price variations for energy supply, the biggest share of the customer's annual electricity cost was delivery (60.6%), not supply (38.9%) over the one-year period we analyzed. Delivery consistently outweighed supply in all four seasons under the Con Edison's MHP scenario.
- In the case of NYPA, most of the delivery charges came from summer months, representing about 20% of the total annual electricity cost. Under NYPA, the customer paid more for supply (57.3%) than delivery (40.7%) for this year.
- Supply cost can be controlled by optimizing energy usage according to price variations and delivery cost can be controlled by managing peak demand during expensive periods.
- OpenADR can help customers reduce their energy bills by automating price response and peak shaving.

It is worth noting that all of our demonstration buildings purchase electricity from a retail access supplier with a flat rate and are not on Con Edison's MHP tariff, though the one building taking their supply from NYPA was on a time-of-day rate. For the purpose of the project, we assumed that the demonstration buildings purchased electricity under Con Edison's MHP tariff and therefore exposed all of their consumption to the day-ahead hourly price variation of MHP.

3 OpenADR in New York State

In this chapter, we describe the key concepts of OpenADR and describe how the OpenADR data model supports all of the common NYISO, utility, REP and CPS interactions with commercial customers in NYS. Individually, these interactions are not complicated. However, as the number of interactions increases, the customer's burden to respond to multiple interactions also increases. OpenADR can simplify this process by standardizing how each interaction will present its signals in a standards-based machine readable format, enabling automated buildings response to benefit of a smarter grid in NYS.

3.1 OpenADR Specifications and Key Concepts

OpenADR is an open and interoperable communication standard that facilitates smart-grid information exchange among ISO, utilities, aggregators, energy services providers and end-users. OpenADR is different than other demand response application protocols, like Smart Energy Profile (SEP) intended for home-based device interactions over advanced metering infrastructure (AMI) based transport [13]. The original OpenADR version 1.0 specification was published in 2009, creating a technical framework for automated communication of price and reliability signals between servers (e.g. utilities) and clients (e.g. end-user) [12]. Building on this framework, the OpenADR version 2.0 specifications have been developed to standardize testing and certification of Auto-DR. This effort is supported by the National Institute of Standards and Technology (NIST) along with organizations including: the Organization for the Advancement of Structured Information Standards (OASIS), the Utilities Communications Architecture International User's Group (UCAIug), and the North American Energy Standards Board (NAESB). The OpenADR 2.0 standard consists of following profiles.

- Profile A (OpenADR 2.0a): is designed for low-end embedded devices to support basic DR services and markets.
- Profile B (OpenADR 2.0b): is designed for high-end embedded devices and includes reporting/feedback capabilities for past, current, and future data reports.

The OpenADR 2.0a and 2.0b specifications are available on the OpenADR Alliance's website.[4]

A new concept introduced in OpenADR 2.0 is the ability to support two types of communication nodes: the Virtual Top Node (VTN) and the Virtual End Node (VEN). The VTN represents a server that publishes and transmits OpenADR signals to end-devices or other intermediate servers. The VEN is a client, an energy management system, or an end-device that accepts OpenADR signals from the VTN and responds to them. An end node can be both a VTN and VEN at the same time. The OpenADR signals are transported via standards-based Internet Protocols (IP) such as Hyper Text Transfer Protocol (HTTP) or XML Messaging and Presence Protocol (XMPP). The message exchange is accomplished in either a PUSH mode or in a PULL mode. In the PUSH mode, the VTN initiates the communication and sends signals to the VEN. In the PULL mode, the VEN initiates the communication by periodically polling updates from the VTN to retrieve the information published by the VTN. The PULL mode can be used to poll day-ahead price signals from ISO or a utility at the client's request.

To use the PUSH mode, the VEN must expose an endpoint URL to create a channel to which the VTN can send price or reliability signals. However, communicating in the PUSH mode can face technical challenges because the VEN may reside behind a network firewall [14]. Moreover, customers may not want to expose the endpoint URL of their server due to network security reasons. In the PULL mode, the network firewall issues can be avoided and the requirement of a server is removed on the VEN. However, the PULL mode introduces latency due to limited polling frequency and requires increased bandwidth [14]. Hence, OpenADR clients should select the mode of communication in consideration of communication needs and technical requirements.

The message exchange patterns for the event PUSH and PULL mode are shown in Figure 5 and Figure 6.

[4] http://www.openadr.org/

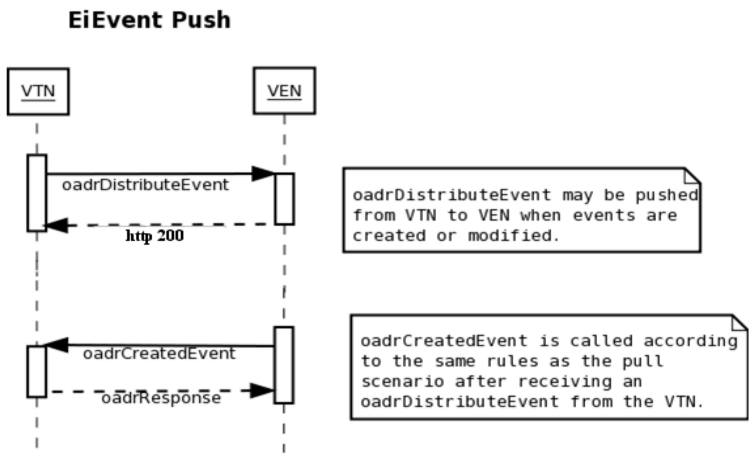

Figure 5. OpenADR 2.0 Event PUSH Pattern (Source: OpenADR 2.0b)

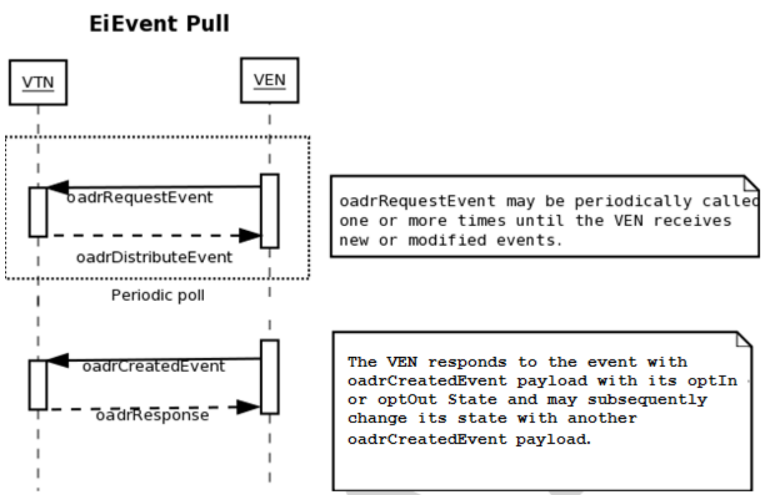

Figure 6. OpenADR 2.0 Event PULL Pattern (Source: OpenADR 2.0b)

Using the PULL mode, the VEN can provide real-time usage data to the VTN by requesting pending service operations from the VTN and then sending the real-time usage data when the communication channel is established. OpenADR 2.0b provides additional feedback and reporting capabilities including historic usage logs, baseline, and forecast which can help aggregators predict and verify the DR performance of their resources.

3.2 OpenADR Sample Use Cases

To show how OpenADR can facilitate smart-grid information exchange among New York stakeholders, we provide two sample use cases: 1) event-driven DR programs and 2) day-ahead hourly pricing. Figure 7 shows the diagram of the event-driven DR programs in NYC. All communication is exchanged in the PULL mode to avoid opening the building's network firewall. An exception is made for the Direct Load Control program in which case customers agreed to allow utilities to control their equipment or systems during DR events.

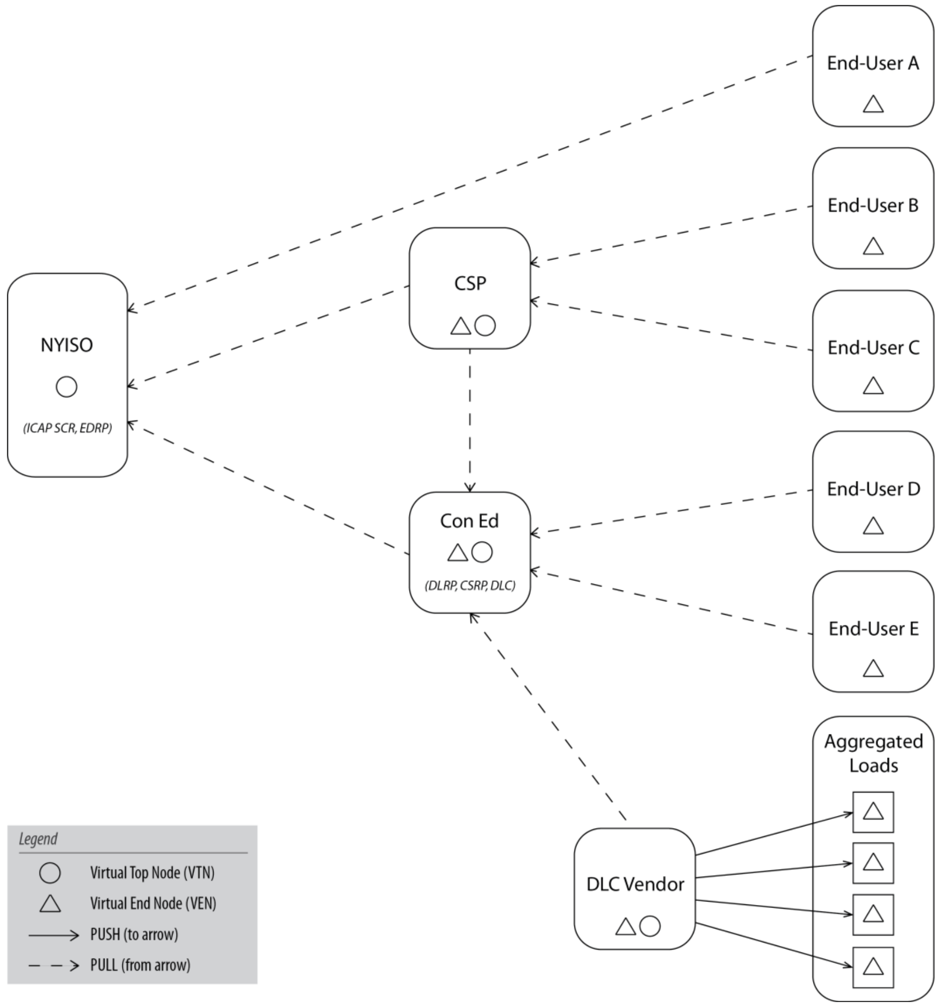

Figure 7. OpenADR communication architecture for event-based DR programs in New York City

Using OpenADR, the NYISO or Con Edison can publish DR event notifications including the program type, date, time, and duration as well as target type (by geographic location, pricing node, or program associations) [14]. Based on the DR event information received from the NYISO or Con Edison, a CSP can activate a DR response for all or selected resource groups. The end-users (i.e. BMS systems or individual devices) can pull the DR event information from the entity where they subscribe their DR participation (likely the CSP). The end-users can respond to the DR event by manually changing control set points or by automatically triggering pre-programmed control strategies via the facility's BMS.

OpenADR communication of dynamic pricing works in much the same way as the event-based DR programs. Figure 8 shows the OpenADR use case scenario for day-ahead hourly pricing in NYC.

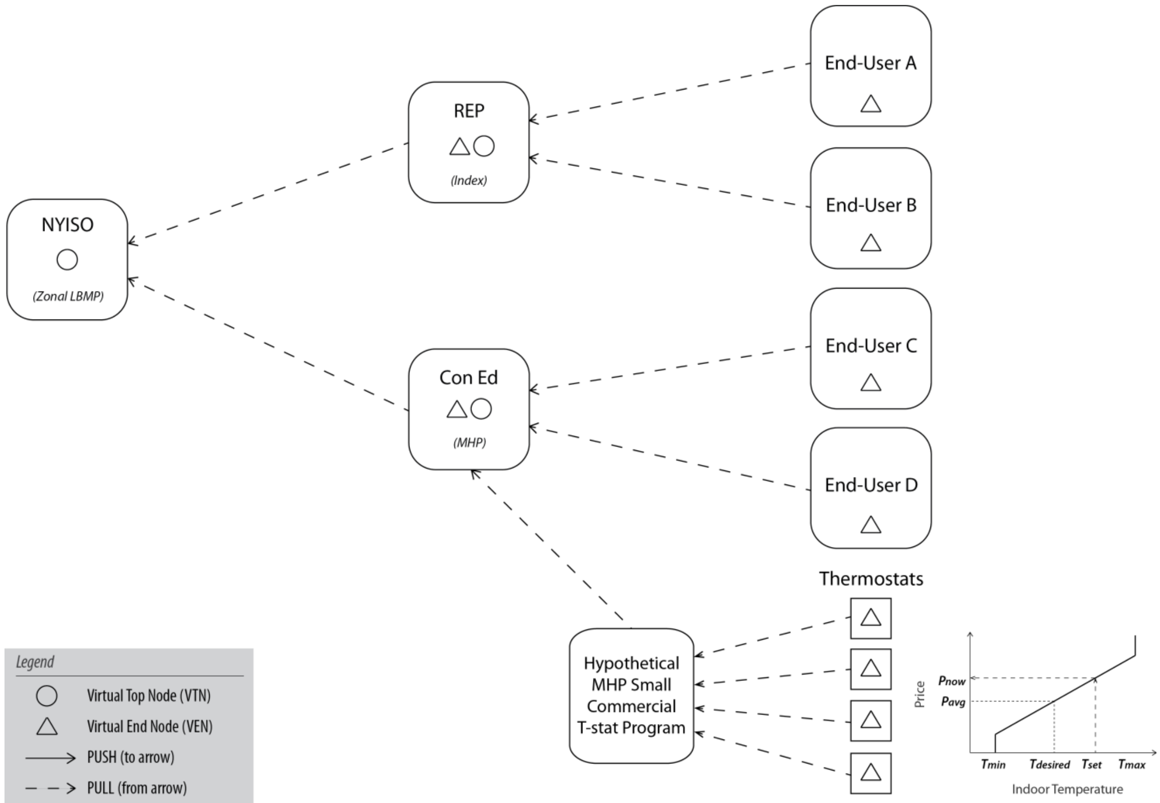

Figure 8. OpenADR communication architecture for dynamic pricing in New York City

OpenADR can be used to publish the NYISO's wholesale prices (day-ahead or day-of zonal LBMP) via OpenADR communication networks. Con Edison and REPs can receive the price signals from the NYISO and determine their rates (i.e., MHP or Index) to reflect the wholesale market variations. End-users who respond to dynamic pricing can pull the price information from Con Edison or a REP from their OpenADR client and manage energy usage accordingly.

There are several manners of varying level of complexity for Auto-DR implemented in the buildings systems of large customers. If the end-user BMS has the real-time processing capabilities, the building's Auto-DR system can change system operations dynamically throughout the day according to the day-ahead price schedule received from Con Edison or a REP. More simply and potentially nearly as effective, a BMS having received the day-ahead price schedule could be programmed with price thresholds above which certain curtailment modes are invoked. Similarly, the utility's or energy supplier's OpenADR server could, as a value added service, translate the price information into simple operational modes (*Normal*, *Moderate*, *High*, *Critical* or *Special* modes) and communicate to the building's Auto-DR system via OpenADR client based on the preferences of the building management. In this implementation, the BMS is not making a decision on how to respond to prices, eliminating the need for a dynamic control algorithm. The OpenADR server (VTN) can have a web application with a user interface where the building management can set thresholds and associate its Auto-DR modes. The site's OpenADR client (VEN) is then, merely triggering those pre-programmed control strategies.

4 Methods

In this chapter, we describe the methods used for Auto-DR implementation at the demonstration sites including communication, hardware and software installation, and DR control strategies. Some of the on-site implementation details had to be tailored to address site-specific conditions such as the existing control systems and buildings automation protocols. However, the overall architecture of the OpenADR information exchange was consistent for all demonstration sites.

4.1 OpenADR Communication Architecture and Security

The information exchange in the demonstration project was accomplished via the Internet. OpenADR 1.0 specification was used as the smart-grid communication protocol to facilitate the communication of price and reliability signals as might be done among customers, the NYISO, Con Edison, and CSPs. The OpenADR 2.0a and 2.0b specifications, which are currently available, were not released at the time of the project implementation; therefore, they were not used for this project. Nevertheless, OpenADR 1.0 profiles were sufficient for communicating day-ahead hourly prices and DR event notifications as would be needed for the most common DR and price signals NYS. Figure 9 shows the OpenADR communication architecture for this project. Our demonstration sites all received DR event notifications from their CSP, not directly from the NYISO or Con Edison.

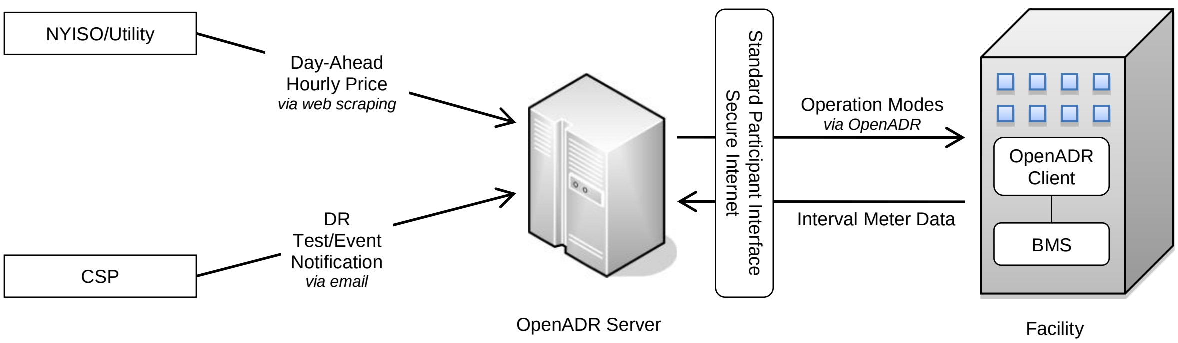

Figure 9. OpenADR communication architecture for the New York demonstration site

Currently, the NYISO, Con Ed, and CSPs do not publish their price and DR signals using OpenADR protocols. To mimic price and reliability signals from these entities, we used a centralized OpenADR server. To generate pricing signals, the OpenADR server scrapes the day-ahead LBMP published on the NYISO's website in tabular format and converts the data into OpenADR signals. This task was automated by the server and is performed daily after the NYISO publishes the day-ahead LBMP. A CSP currently sends DR test/event notifications to the customer via email. During the demonstration the OpenADR server would receive the same email and convert the message into an OpenADR signal(s). Upon receiving the OpenADR signals, the site's OpenADR client activates pre-programmed control strategies via the facility's BMS. The OpenADR server also collects electric meter data for monitoring purposes. All information exchange was accomplished through a secure Internet connection with 128-bit Secure Sockets Layer encryption.

Akuacom, a Honeywell subsidiary, provided the OpenADR server called the Demand Response Automation Server (DRAS) for this project. The security policy which governs the DRAS is largely based on the NIST's Interagency Reports 7628: Guidelines for Smart Grid Cyber Security. Appendix A includes the cyber security plan for the DRAS. The North American Electricity Reliability Corporation's Critical Infrastructure Protection Standards (NERC-CIP) provides comprehensive security requirements for critical cyber assets in the bulk electric system. It is mandatory for selected assets that belong to the Responsible Entity category.[5] The DRAS does not fall under the NERC-CIP requirements because it controls less than

[5] NERC-CIP is mandatory for Responsible Entity (control centers and backup control centers, transmission substations, generation resources, systems and facilities critical to system restoration, automatic load shedding capable of shedding 300 MW or more, special protection systems, and any additional assets that support reliable operation of the Bulk Electric System [15].

300 MW of potential shed. However, its security policy was written with NERC-CIP requirements in mind; hence, it is capable of supporting the NERC-CIP requirements.

4.2 Auto-DR System Design and Configuration

A site's Auto-DR system design and configuration depends heavily on the capabilities of existing control systems and communication protocols. It is common for large commercial buildings to have several control systems and devices (i.e., HVAC, lighting, electric, security, etc.) used for building operation. A centralized BMS integrates individual control systems/devices to provide greater controllability and efficiency to building managers. Installing a centralized BMS can be a seamless process if all systems/devices use an open building automation communication protocol, which facilitates interoperability between different vendors' systems. However, this is not always the case due to different communication protocols used across control systems/devices in the same building.

The building automation communication protocols are largely grouped into two categories: proprietary and open protocols. Proprietary protocols are vendor-specific and used for individual control. Open building automation communication protocols are vendor-neutral supporting all building systems and devices equally and used within a building. The open protocols such as BACnet, Modbus, and LONWORKS are standard communication protocols for building automation and control. They provide interoperability between different vendors' systems. The use of an open building automation communication protocol is advantageous for Auto-DR when multiple systems/devices need to respond to the same OpenADR signals. Three of the four demonstration sites' BMS use BACnet as the building automation communication protocol and one building uses a proprietary protocol.

<u>Equipment Installation and Programming</u>

Each demonstration building had a vendor-specific BMS, namely Honeywell's Enterprise Buildings Integrator (EBI), Automated Logic Corporation's WebCTRL®, Schneider Electric's Andover Continuum, and Johnson Control Inc.'s Legacy respectively. Honeywell provided the overall system design and equipment installations for the project and the services at each site. Programming of the control strategies for EBI was done by Honeywell's engineering team. As for WebCTRL®, Andover Continuum, and Legacy, subcontractors were hired for programming in each vendor's software. Most of the control strategies were HVAC-related. We proposed lighting strategies for two buildings in addition to the HVAC strategies. However, the lighting system was not integrated into the BMS prior to the project and additions would increase costs and further delay the project.

None of the buildings had BMSs that were natively equipped with an OpenADR client. An OpenADR client was provided within a gateway device called a Java Application Control Engine® (JACE®) box, in each of the four buildings to provide connectivity between DRAS (VTN or OpenADR server) and building systems/devices. A physical connection (via a meter splitter or a direct line) was made between JACE® and the building's electric meters to poll meter readings via kyz pulses. The meter data was sent from JACE® to DRAS for monitoring purposes. Currently, the meter data is being polled at a 15-minute interval to match the interval of Con Edison's meter reading. However, JACE® can increase the polling frequency (i.e., 5-min or 1-minute) as long as the building's network bandwidth can support. In recent years, a number of vendors have begun to offer OpenADR embedded BMSs so that BMSs can directly send or receive OpenADR messages without a gateway device such as JACE® box.

<u>Open Protocol</u>

For the buildings using BACnet as the communication protocol, the JACE® translated OpenADR signals into BACnet messages and sent them to Honeywell's ComfortPoint™ Open Plant Controller (CPO). The CPO is a computer where Auto-DR intelligence resides. It maps each OpenADR signal into target systems/devices through a BMS according to pre-programmed control strategies. The CPO also hosts a web-based user interface (UI) for building managers to opt in/out of individual control strategies. The UI can be accessed remotely over the Internet. The Auto-DR system configuration using BACnet is shown in Figure 10.

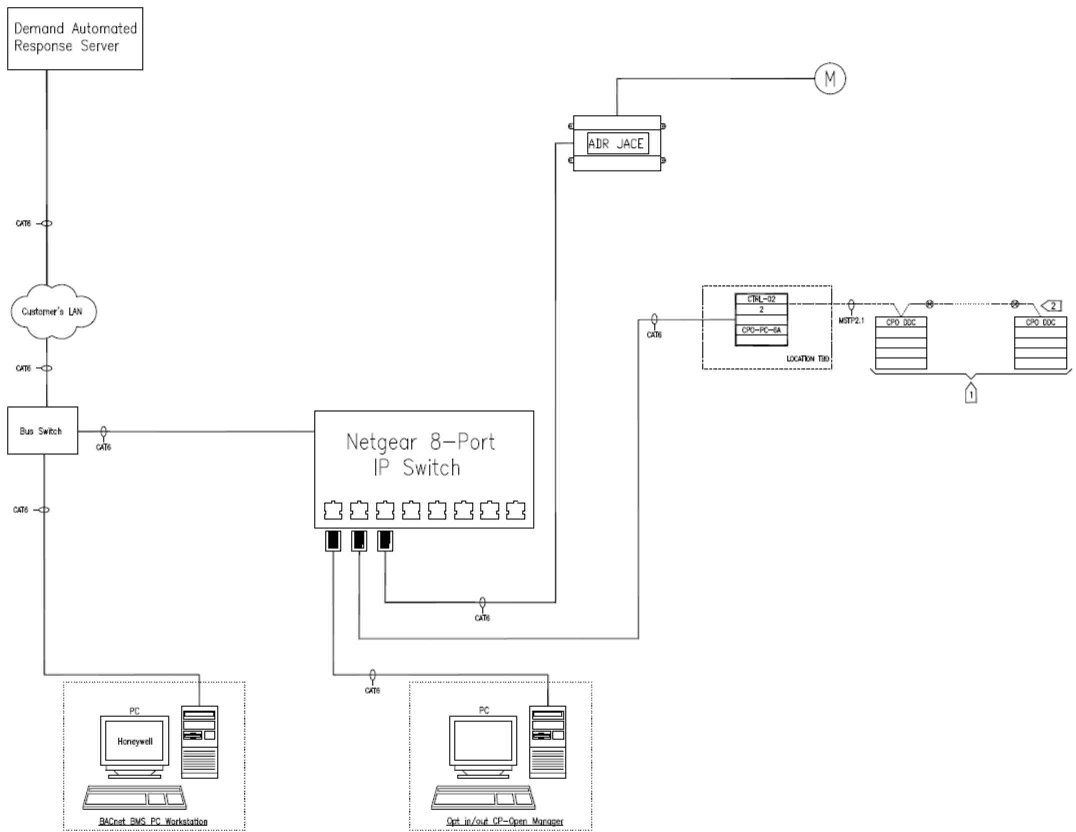

Figure 10. Auto-DR System Configuration for Buildings with Open Protocol

<u>Proprietary Protocol</u>

One building used Legacy BMS which communicated using proprietary protocol. Since there was no common communication protocol across the systems/devices, we provided a physical connection between the JACE® box and and Legacy system. The installation of a CPO was not necessary since the direct connection was established between the JACE® box and Legacy system. For simplicity, the project's implementation provided building managers the ability to opt-out of Auto-DR via the DRAS client interface accessible over the Internet. Since the CPO is not installed in this building, the building managers cannot opt-in/out of individual control strategies which reside within their on-site Auto-DR control system. The Auto-DR system configuration for this building is shown in Figure 11.

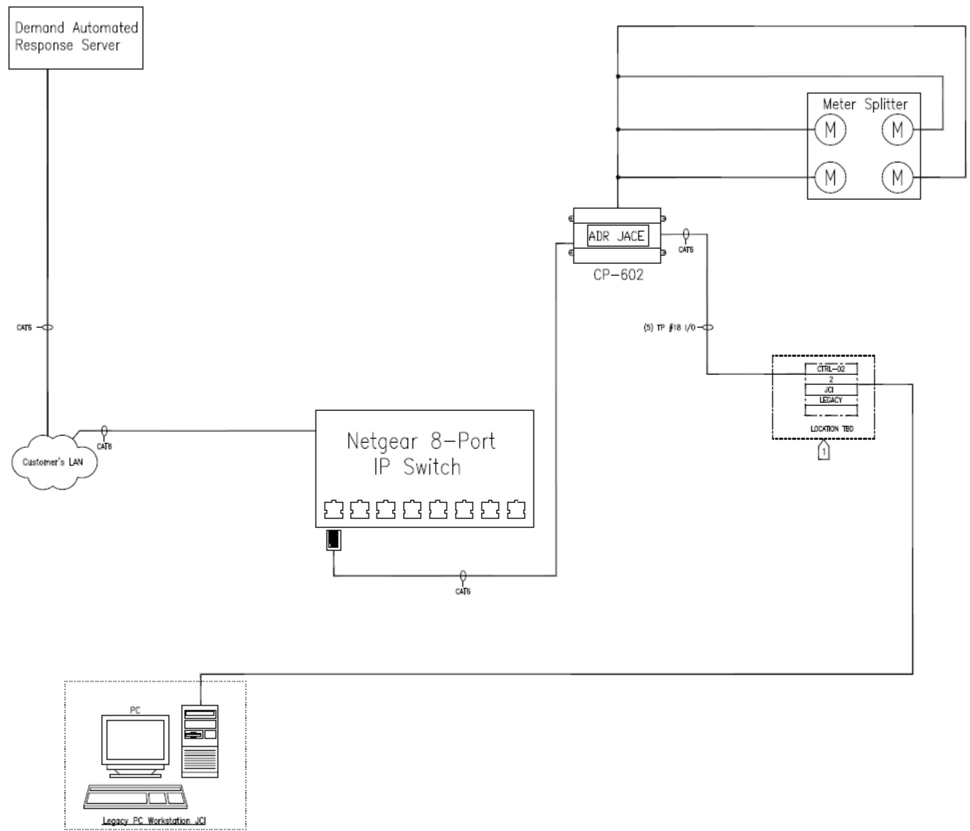

Figure 11. Auto-DR System Configuration for Buildings with Proprietary Protocol

<u>Other Potential Approaches</u>

Some new BMS products have an embedded OpenADR client and advanced programming capabilities. For these BMSs, one could simplify the Auto-DR system configuration by removing layers such as the CPO and JACE® . Though this approach was not demonstrated in this project, this configuration illustrates the simplicity that OpenADR could bring to enabling Auto-DR capabilities and the potential to greatly reducing the project hardware, cost, and complexity. Additionally, if smart meters where installed can communicate using open protocols, the OpenADR client can poll meter data without having to split the existing electric meter or create a physical connection to it. As more systems/devices use open protocols, more effort will be devoted to software development in Auto-DR implementation instead of hardware installation. Programming costs would grow marginally as greater control is extended over additional components and systems.

4.3 Site Auto-DR Curtailment Modes and OpenADR Signals

For the sites in this project the levels of load shed at each site are embodied in curtailment modes – *Moderate*, *High*, and *Critical* preprogrammed in the BMS. This project does not demonstrate real-time on-site optimization of a building's cost or peak demand objective function. For simplicity of implementation, the sites' BMS is not programmed to decide which mode to use. Rather, this project uses the DRAS functionality to select the sites' *Moderate*, *High* and *Critical* curtailment modes based on their response preferences (i.e., price thresholds, demand threshold, DR event notifications). The DRAS selects the mode according to the preferences and bundles it with other necessary information, like duration, start and end times in an OpenADR signal tailored for each site. This demonstrates how a retail energy supplier, a curtailment service provider, or even a utility can offer its customers a valuable service that makes Auto-DR implementation simpler for its customers.

Each mode initiates curtailment from the Auto-DR enabled building systems. The curtailment level and therefore the operation mode is determined based on price and reliability signals as well as the demand limiting program (Figure 12).

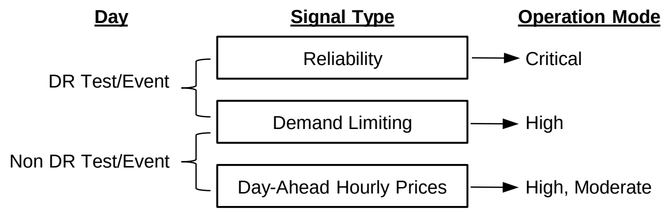

Figure 12. Automated demand response signal prioritization

For non-DR test/event days,

- The site's BMS responds to price signals in an automated fashion. If the building's electric demand is nearing a preset demand threshold, the demand limiting program will be activated until the demand returns to an acceptable level. At this point, price response resumes.

For DR test/event days,

- The site's BMS responds to reliability signals from a CSP during the DR test/event period.
- Price signals and the demand limiting program are turned off or ignored during and prior to DR test/event periods to prevent shed activities affecting the customer's baseline with morning adjustment for energy compensation. This is applicable to those whose default energy baseline is NYISO's Weather-Sensitive Customer Baseline[6].

OpenADR provides four types of signals related to load shed: *Normal*, *Moderate*, *High*, and *Special* (which we call *Critical* for this project).

- *Normal* indicates the normal operation triggered when the energy price is acceptable and there is no DR test/event issued.
- *Moderate* indicates the first level of load shed triggered when the energy price is moderately expensive.
- *High* indicates the intermediate level of load shed triggered when the energy price is highly expensive. *High* is also triggered when electric demand exceeds the pre-set threshold.
- *Critical* indicates the highest level of load shed triggered when the DR test/event is issued and electric loads need to be curtailed at the maximum reduction level.

[6] which uses 2-4 hours of load data prior to the DR test/event to adjust the Average Customer Baseline (CBL) [16].

5 Site Implementation

Auto-DR implementation was accomplished through the teamwork of LBNL and industry partners including Honeywell and Akuacom. Honeywell provided site enablement and equipment installation. Akuacom provided OpenADR server solutions. LBNL developed technical specifications and Auto-DR control strategies as well as coordinating and managing the overall project. In this chapter, we introduce the demonstration buildings and discuss Auto-DR control strategies developed for each building.

5.1 Site Description

Four buildings were recruited for the demonstration project. Preferences were given to the buildings that represented the typical construction of commercial buildings in NYC. All demonstration buildings previously participated in one or more incentive-based DR programs through CSPs. Prior to this project, DR at these buildings was provided through manual control of HVAC, lighting, and other systems. Some also provided manual peak load management. But because DR was manually performed, the buildings did it only on hot days or DR event days. They did not do any price response because it requires frequent DR. The customer's participation in this project was driven by the motivation to automate DR. Figure 13 shows the location of the four demonstration sites.

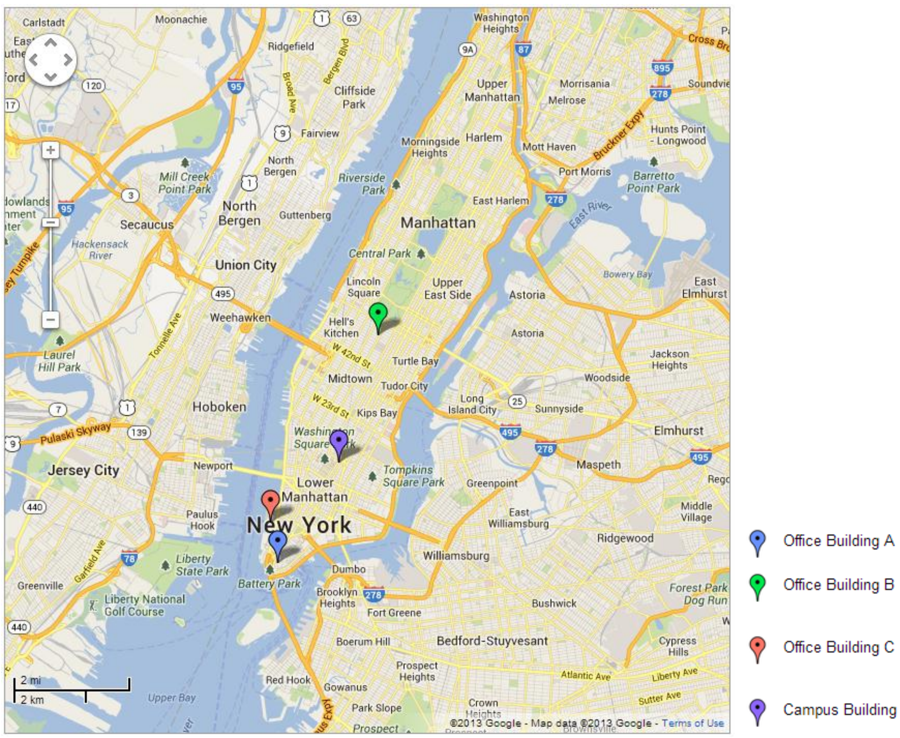

Figure 13. Demonstration Site Location (Source: Google Map)

Table 3 summarizes the business type, floor space, peak demand, energy supplier, DR program enrollments, and contracted CSPs. More detailed description of the demonstration sites is provided in Appendix E. As mentioned earlier, all sites purchased electricity from a REP through retail access.

Table 3. Demonstration Site Summaries

Facility	Business Type	Peak Load (kW)	Floor Area (ft^2)	Peak Load Intensity (W/ft^2)	Load Factor	Annual Consumption (kWh)	Electricity Supplier	Demand Response Program Enrollment	Curtailment Service Provider
Office Building A	Office	6,190	1,400,000	4.4	0.51	27,612,000	NYPA	NYISO SCR & EDRP	Energy Curtailment Specialist
Office Building B	Office	3940	1,700,000	2.3	0.52	8,717,000	Direct Energy	NYISO SCR & EDRP ConEd DLRP & CSRP	iES
Office Building C	Office	4640	1,400,000	3.3	N/A	24,782,000	NYPA	NYISO SCR Con Ed DLRP	Constellation
Campus Building	Campus	600	122,000	4.9	0.39	2,150,000	NYPA	NYISO SCR & EDRP	Comverge

Prior to developing Auto-DR control strategies, we assessed DR opportunities and limitations for each site based on historic interval meter data, building systems, control capabilities, and operational constraints. We also reviewed the buildings' previous DR performance and evaluated past control strategies.

Site-specific opportunities and challenges are summarized as follow.

- *Office Building A* – The building had more predictable energy usage patterns due to a fixed operation schedule and a good track record of DR performance. Weekends are ideal for night flushing. The site starts precooling at midnight on DR event days as well as on warm days throughout the summer. Global Temperature Adjustment (GTA) is currently not available. A limited lighting control is available through a separate security system but it is not integrated into the BMS.
- *Office Building B* – The building had relatively low summer electricity use due to the onsite generation using steam. The trade-off between electricity and steam under dynamic pricing scenario is unknown but would be worth exploring.
- *Office Building C* – Two buildings were considered for Auto-DR: Tower A and Tower D. Tower A is used for office and Tower D is used to host the site's central plant. Tower D has a large thermal storage capacity (3 million gallon), which provides cooling to multiple buildings. For this phase of the project, we will not include the use of thermal storage for Auto-DR because it requires coordination between all buildings that are affected. Auto-DR efforts are focused on Tower A only.
- *Campus Building* – The building went through a major renovation and was occupied again in September 2011. The building is in operation 7 days a week. The energy consumption pattern showed some variability depending on the class schedule and school holidays. Automating lighting control could enhance the DR capabilities of this building.

5.2 Auto-DR Control Strategies

As the role of CSPs has expanded in NYS's wholesale energy market, innovations in building automation products and services for DR resource management have increased [17]. Auto-DR can add business value to CSPs by improving dependability and repeatability of their DR resources. All of our demonstration sites had and continue to work with their own CSP to provide load reductions during DR events. Each site had a list of control strategies that they used during DR events, typically manually, to meet the target load reduction requirements by CSPs. From their existing control strategies, we selected the ones that can be automated through the facility's BMS and grouped them into *Moderate*, *High*, and *Critical* operation mode as shown in Table 4.

Table 4. Auto-DR Strategies for Demonstration Sites

Facility	Operation Mode	Global temperature adjustment	Precooling	Supply fan speed reduction	Exhaust fan quantity reduction	Chilled water temperature increase	Chilled water pump speed reduction	Shutting off chilled water pumps	Chiller quantity reduction	Condenser water temperature increase	Shutting off condenser water pumps	Slow recovery	Sequential equipment recovery	Extended DR control Period	Turning off lighting in auxiliary space
Office Building A	Critical	x	x	x	x	x	x	x	x	x	x	x	x	x	P*
	High	x	x	x	x	x	x			x	x	x	x	x	
	Moderate	x		x		x				x	x	x	x	x	
Office Building B	Critical			x	x		x			x		x	x	x	
	High			x	x		x			x		x	x	x	
	Moderate			x			x			x		x	x	x	
Office Building C	Critical			x	x			x				x	x	x	
	High			x	x			x				x	x	X	
	Moderate				x			x				x	x	x	
Campus Building	Critical	x	x	x	x						x	x	x	x	P*
	High	x	x	x	x						x	x	x	x	P*
	Moderate	x		x							x	x	x	x	P*

*P: Pending

The strategies involving starting chillers during non-operational hours (i.e., precooling) could not be automated because they require a site engineer to be present by the NYC Fire Code. At the request of customers, Global Temperature Adjustment (GTA) was added to *Office Building A* to increase DR capabilities. The feasibility of adding lighting automation to *Office Building A* and *Campus Building* was discussed but the decision is pending. As for elevators, we recommended that the building managers maintain manual control over their elevators for both DR and non-DR days. To minimize the post-DR rebound effects of electricity demand, *Normal* operation mode would return slowly according to preprogrammed sequential equipment recovery. If there is less than one hour left until the end of occupancy period, DR is extended to the end of the occupancy period and then the building returns to *Normal* operation mode.

6 Conclusions

In this report, we provided progress updates on Auto-DR implementations, presented customer bill control opportunities, Auto-DR implementation methods, and DR control strategies for the project's demonstration buildings. The demonstration buildings are automated to provide event-driven demand response, price response, and demand management according to OpenADR signals. Control strategies are designed to curtail customer's load as per day-ahead hourly prices and demand charges as well as DR events. HVAC control strategies were often the first to be automated because they were effective at lowering demand and they could be controlled through the facility's BMS. The strategies involving starting chillers during non-operational hours (i.e., precooling) could not be automated because they require a site engineer to be present by the NYC Fire Code. The implementation of Auto-DR system in demonstration buildings heavily depended on the existing control systems and communication protocols. The building systems that used an open building automation communication protocol were easier to automate than the ones used proprietary protocols because the open protocols could speak to multiple systems/devices manufactured by different vendors to activate control strategies according to OpenADR signals.

To date, we concluded that 1) OpenADR can support the price and DR interactions defined by the deregulated and restructured market in NYS; 2) price response to day-ahead hourly pricing can be made easier through Auto-DR; and 3) Auto-DR helps customer's DR participation by eliminating human labor and costs to provide DR and making it a repeatable and error-free process.

Auto DR enablement and commissioning at all sites were completed in early summer 2013. The DR testing has taken place throughout the summer and fall of 2013. The final report will provide details of the DR testing and discuss load reduction quantification and customers' utility bill analysis with Auto-DR. Chapter 7 discusses some of the research opportunities that can leverage the Auto-DR infrastructure that is established through this project.

7 Future Research

Several potential future research ideas arose that could leverage the Auto-DR infrastructure established through this project.

Dynamic Load Control

Simple threshold-based load control can provide only a few levels of load sheds based on pre-programmed strategies. For customers who wish to have greater control over energy use and cost, dynamic load control and objective function optimization could be investigated. If a building is participating in price response as an individual facility, the building must possess data/decision processing power and centralized control. If one or more devices or systems in buildings are flexible for price response as a part of an aggregated group, each system or device should possess data processing power and controls. Developing the algorithm that can optimize energy use based on cost and occupant comfort would be an important piece of dynamic Smart Building load control. The algorithm should have closed loop feedback and monitor real-time feedback such as electric load and zone temperature to ensure the target performance is met. Creating this capability can provide customers a layer of protection against dynamic pricing and demand charges, as well as ensuring occupant comfort.

Location of Intelligence and Impact on Flexibility and Cost

The intelligence of Auto-DR can reside 1) in the facility or 2) in the cloud. While the first option has the advantage of unrestricted building data retrieval and direct control over the building systems/devices, it requires on-site development and operation of Auto-DR software. If the Auto-DR software is programmed by a third-party contractor, the contractor has to be brought in to make any changes to the software. This may not be practical for the buildings that want to modify DR control strategies from time to time. Locating the intelligence in the cloud has the advantage of flexible energy monitoring and DR management. Cloud computing also offers remote data storage and processing capabilities. Multiple buildings and systems can be managed remotely from a variety of locations without the upfront and ongoing cost of having a smart building automation system. For this reason, cloud-based Auto-DR can add a significant value to small/medium buildings by reducing the on-site hardware and software installation cost. However, the availability of building control and real-time feedback may be restricted if the building does not want to open their network firewall. Moreover, building managers may be opposed to the idea of their building being controlled by remote intelligence. A study on the location of intelligence and its implications on the flexibility and costs of Auto-DR as well as network security would be valuable for field applications as well as data analytics needs.

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Appendix A: DRAS Cyber Security Plan

DRAS Cyber Security Plan

Akuacom

San Rafael, CA

Honeywell International, Inc.

Full Scale Implementation of

Automated Demand Response

November 30, 2011

Honeywell

TABLE OF CONTENTS

INTRODUCTION AND OVERVIEW

INTRODUCTION

Based in San Rafael California, Akuacom provides technology and services for Automated Demand Response (Auto-DR). Akuacom's open and interoperable Smart Grid messaging infrastructure is used by utilities and ISOs to automate the delivery of DR price and reliability signals to aggregators, commercial and industrial facilities, and residential buildings. At the core of the messaging infrastructure is Akuacom's Demand Response Automation Server, or DRAS, a software service platform that fully supports OpenADR.

Akuacom has over a decade of experience implementing end to end enterprise control systems for Energy Management and Building Control.

Akuacom has hosted the Demand Response Automation Server (DRAS) for pilots since 2005 and in live utility programs since 2006. During this period of deployment, several cyber security verification processes have occurred, and Akuacom has consistently worked on maintaining state-of-the-art conformance to cyber security mechanisms.

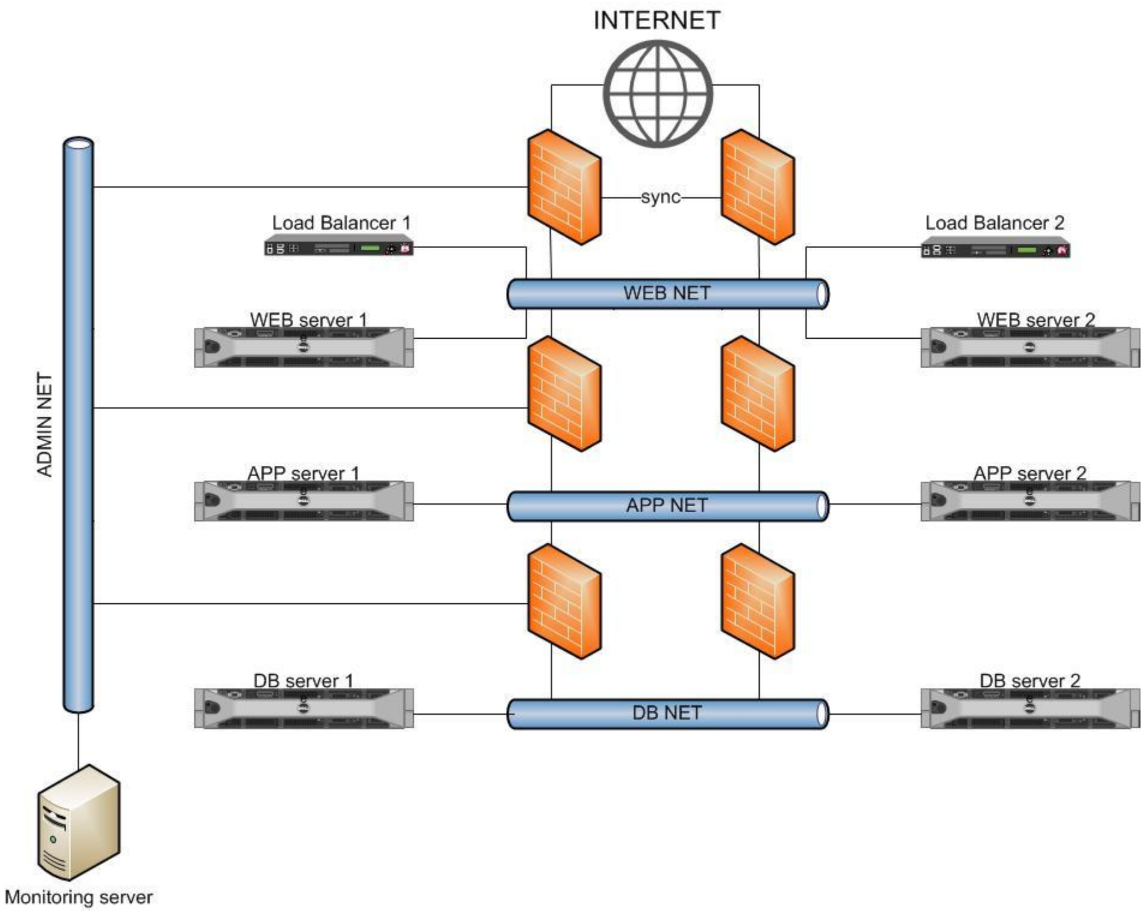
OVERVIEW

This system security plan will demonstrate DRAS security from software, hardware, network, use of standard, and software/service process control.

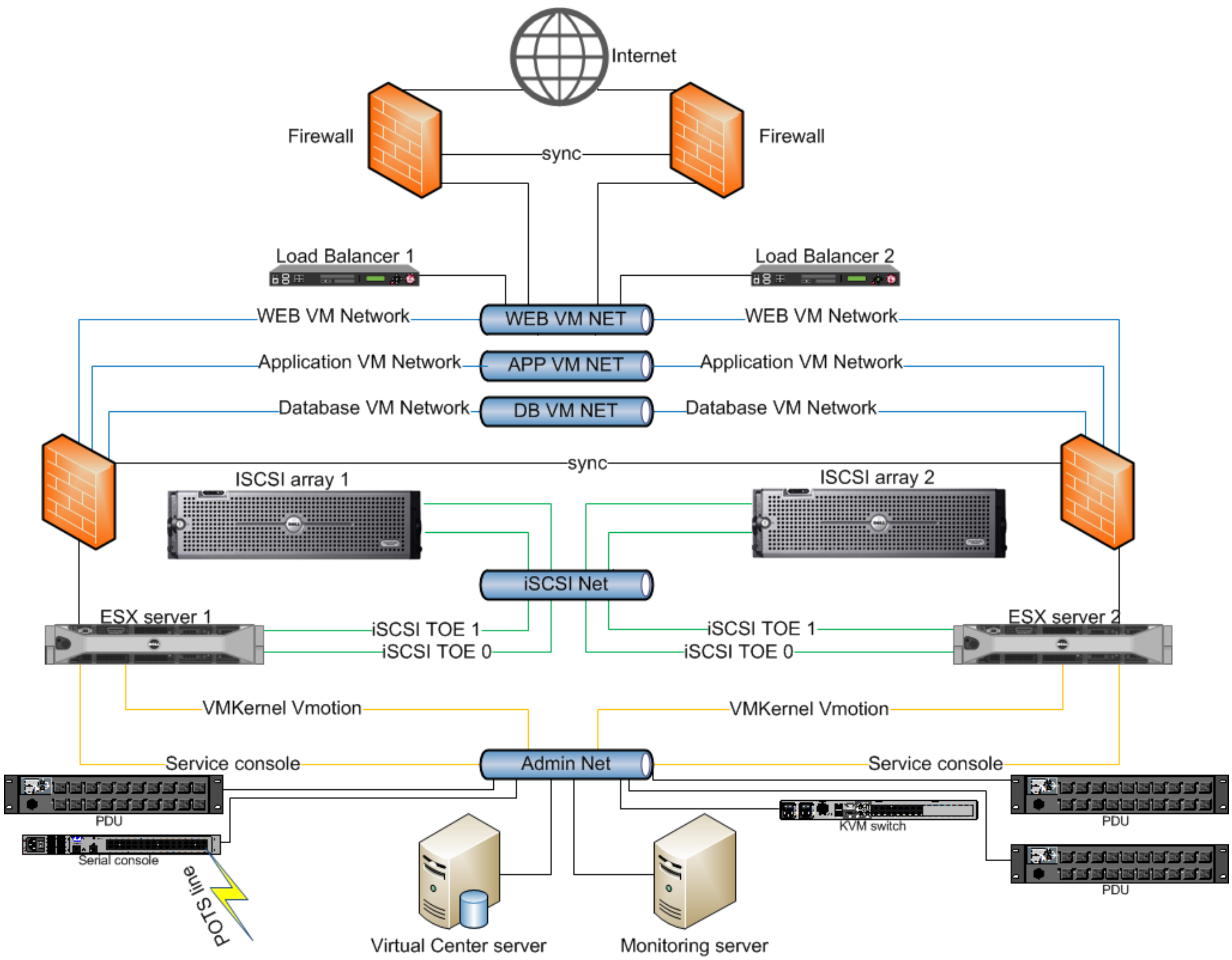
DRAS INFRASTRUCTURE OVERVIEW

SYSTEM ARCHITECTURE

Logical Application Component Separation



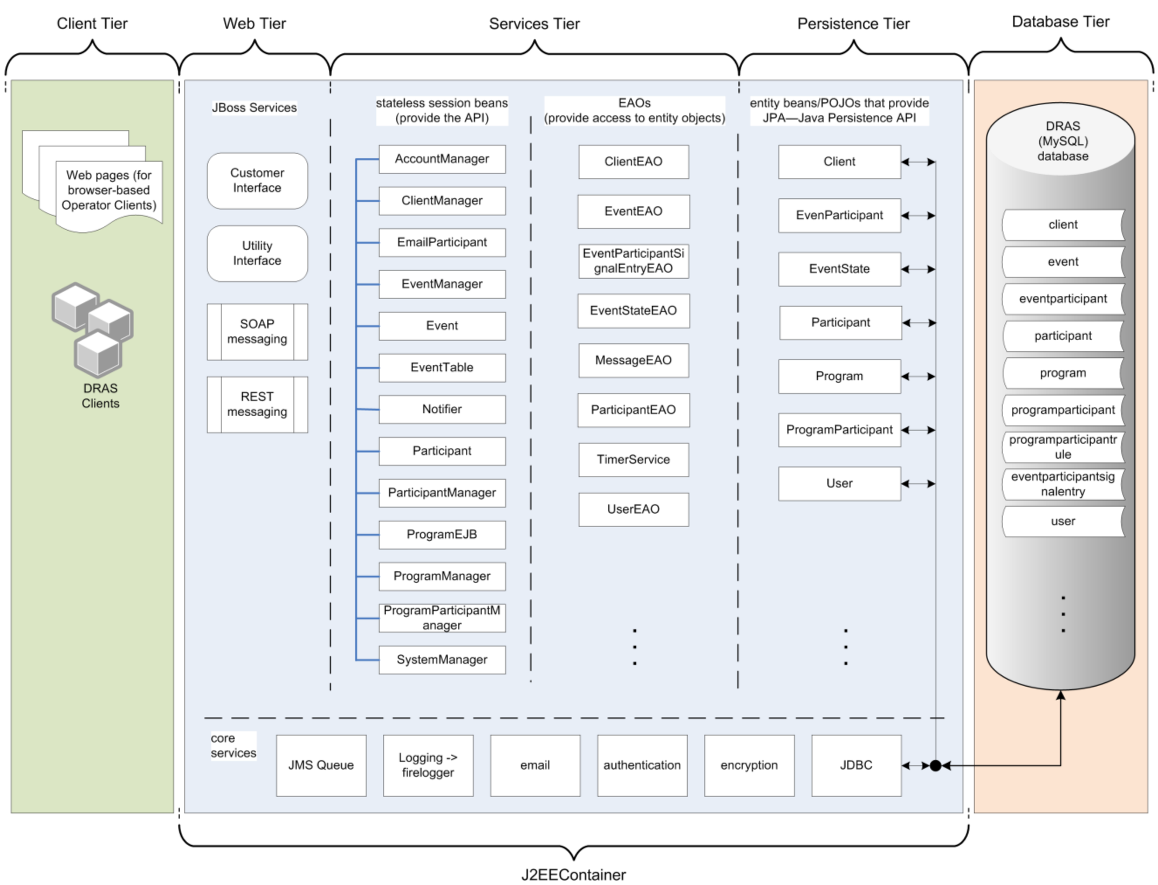
LOGICAL NETWORK ARCHITECTURE



APPLICATION ARCHITECTURE

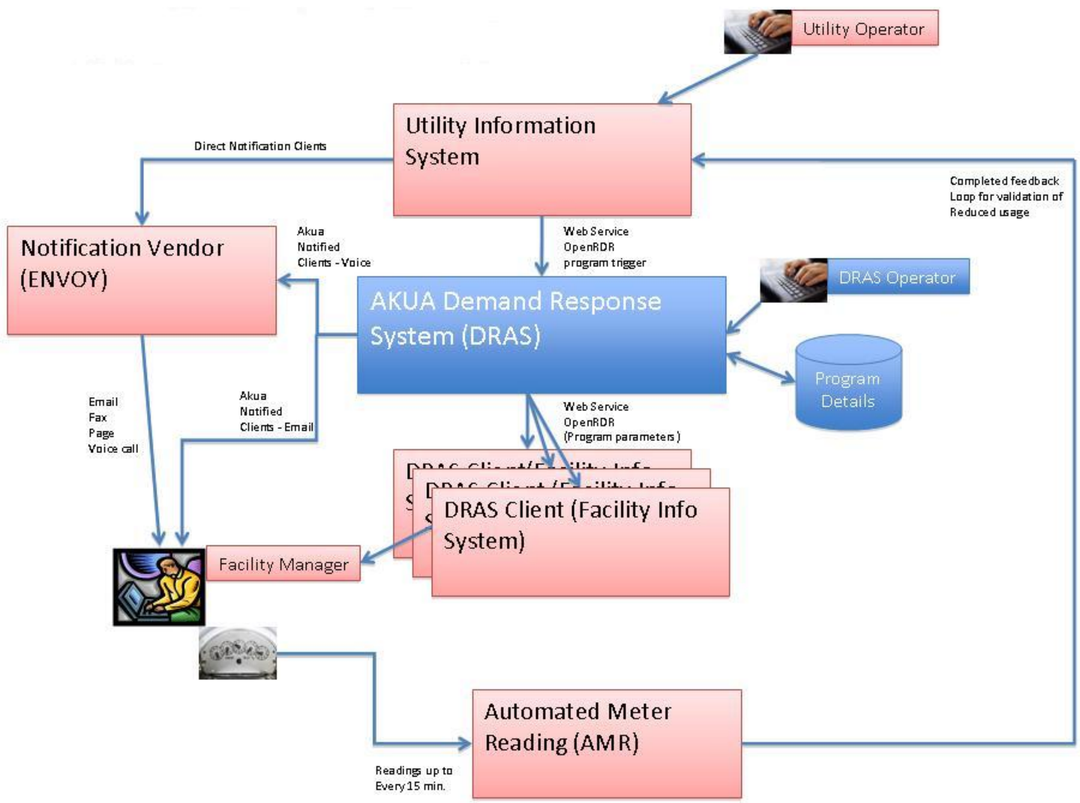
The DRAS architecture model is a standard Java 2 Enterprise Edition (J2EE) implementation and standard servlet technologies (provided by the embedded Tomcat Web container) that talk to Stateless Enterprise Java Beans (EJBs), which in turn communicate with a MySQL database via Entity Beans.

The Web tier, Service tier and Persistence tiers are deployed into a single container via an enterprise archive (EAR). Because JBoss does not need to serialize data transfer objects to remote clients, system performance is optimized. Additionally, physical deployments are greatly simplified, and data communication between physical servers is also minimized. If required by future deployments it's simple to separate Web applications from each other and/or the Persistence tier.



DRAS Application Diagram

The following diagram illustrates a typical data flow where Utility Operator can view the program/participant information and issue event from Utility Operator Interface through HTTP/HTTPS request or from 3rd party tools through OpenADR WebService. Subsequently, DRAS server dispatches notifications to all the corresponding contacts. Specific Signal will be dispatched to the DRAS client (JACE) through OpenADR WebService and corresponding shed will be applied to its BMC system. The usage data is collected through JACE and fed back to DRAS through ObixDRAS WebService.



DRAS Data Flow

DRAS SECURITY INFRASTRUCTURE

Akuacom has hosted the Demand Response Automation Server (DRAS) for pilots since 2005, and in live utility programs since 2006. During the period of deployment, several cyber security verification processes occurred, and Akuacom has consistently worked on maintaining state-of-the-art conformance to cyber security mechanisms. The DRAS was developed with fundamental security architecture concepts from the outset:

TRANSPORT LAYER SECURITY/SECURE SOCKETS LAYER (TLS/SSL)

To prevent eavesdropping and data tampering, the connection for DRAS data communication between the various clients and server is protected with TLS/SSL protocol. The DRAS presents a server SSL certificate issued by a well known certificate authority. The client will contact the server that issued the certificate and confirm the validity of the certificate before proceeding. Symmetric cryptography is used for data encryption (e.g., DES [DES], RC4 [SCH], etc.). Message transport includes a message integrity check using a keyed MAC. Secure hash functions (e.g., SHA, MD5, etc.) are used for MAC computations.

JAVA AUTHENTICATION AND AUTHORIZATION SERVICE (JAAS)

The DRAS Application Servers are integrated with the Java Authentication and Authorization Service (JAAS), which augments Java code-based security with a Java security framework for user-centered security. JAAS provides user authentication management through:

- Authenticate all the DRAS clients including Utility Operator UI, Utility Customer UI, and web service end points.
- Implemented strong password policy (9 characters, upper and lower, special character, Alphanumeric)
- Encrypt passwords in database, don't allow clear text password display via web site
- Role based access control: super admin, utility operator, installer, facility operator, and web service client for device.

- Only allow access to Account Manager web site via internal IP addresses and used VPN, if remote access is necessary.
- Block JBoss console from internet access.
- Block JMX Console from internet access.

SESSION CONTROL

- For the web-based user tools such as Utility Operator UI and Utility Customer UI, system force logs out after 10 minutes of inactivity, and you must log in again to continue working.
- Single Sign On (SSO) to allow session transfer between various application domains.
- Plug-in login modules to simplify the 3rd party application integration.
- Suppress Web UI Error messages

MULTI-LAYER CLIENT/SERVER INFRASTRUCTURE

Akuacom has completed implementation of a multi-tier architecture that separates web access from application data access. There are firewalls between each of the architecture layers to insure that only very specific application packets can get through to the database to do very narrow queries.

DRAS WEB SERVER SECURITY:

- The DRAS Web Server (Apache httpd server) is located in DMZ which is separated with firewall from public Internet. It is only through the DRAS Web Server that the DRAS services are exposed to the Internet. By limiting exposure of the DRAS services this way, and by extension preventing direct access to the DRAS Application Servers, security is greatly enhanced.
- The DRAS Web Server contains no application data, so even if an external hacker gains access to this server, no data is compromised.

DRAS APPLICATION SERVER SECURITY:

- Communication to the DRAS Application Servers is restricted to a single transaction type on port 9009, which ensures that no unexpected or invalid requests could cause the Application Server to operate improperly or expose data inappropriately.
- Commonly hacked ports, and their corresponding applications, cannot be reached. For example, nothing can get through the FTP port.

DRAS DATABASE SECURITY:

- In the DRAS Application Servers, JBoss communicates directly with the MySQL database through port 3306, and no general queries are possible without super user access. This prevents any unauthorized application from communicating with the database, thereby ensuring data security

FIREWALL AND SYSTEM SECURITY CONTROL

Three layers of firewall guard the DRAS system from cyber attack: firewall between public Internet and DRAS web server, firewall between DRAS web server and DRAS application, and firewall between application server and database server. To enable DRAS to operate, firewall policies must allow the following,

DRAS APPLICATION SERVER:

- Port 9009—for Apache JServ Protocol (AJP) connections
- Port 25—for SMTP (email)
- Port 22—for SSH
- Port 123—for NTP

DRAS DB SERVER:

- Port 3006—for JDBC connections
- Port 22—for SSH
- Port 123—for NTP

DRAS WEB SERVER:

- Ports 80 and 443—for HTTP and HTTPS

The DRAS servers all reside in Linux system. Akuacom does not recommend installing virus protection on the Linux server. Symantec and other anti-virus companies do provide virus checking software for Linux, but that is exclusively when the Linux box is used a client with a user front end Graphical Interface on the Linux server. The DRAS server does not have a GUI and utilizes JBOSS exclusively to communicate with the web server.

The majority of virus checking that is performed on Linux severs is to ensure that the Linux-based mail server does not propagate Window's viruses. In the case of a Linux server that is used for mail hosting, this is an important reason to install Virus protection. The DRAS does not host a mail server and sends text based mail messages to the 3rd party mail server. There would be no value in installing this type of virus protection as we are not hosting mail on the Akuacom DRAS Linux server.

The recommended security procedures for Linux is to restrict the running services to the minimum needed for the application and to install a firewall between the Linux box and the internet that restricts the port set to a known list of application ports. Both of these have been done for the Akuacom DRAS server.

Most firewall products support a virus checking module and for Linux server based applications, that is the best place to install virus checking. The commercial solutions that are available for Linux servers are more configuration management and change detection tools that can be used in large Linux environments to ensure that environmental integrity is maintained. An example of this type of product is Tripwire for Servers. These products are hard to install and are tailored to a full Linux IT environment, not a single server and Akuacom does not recommend the installation of these products.

DRAS APPLICATION SIGNAL CONTROL AND DATA SENSITIVITY

The DRAS does not currently support direct load control of devices. All of the load management that the DRAS controls is indirect. The DRAS sends OpenADR signals to facilities and the facilities execute pre-programmed shed strategies based on the signal levels. This fact limits the amount of damage an intrusion could cause. The following provides an analysis of the potential impacts to the grid in the event of a successful intrusion into the DRAS:

USE OF STANDARD

The DRAS utilizes both external standards for communications with the client devices and internal standard components for the server implementation. The client devices communicate with the server with the OpenADR protocol.

OPENADR

OpenADR was developed by Lawrence Berkeley National Laboratories (LBNL) Demand Response Research Center as a result of research that begun in 2002. The goal of the research was to develop a signaling means to enable the automation of end-use control for the purposes of Demand Response. The original OpenADR specification was published by the California Energy Commission.

The delivery of OpenADR messages does not rely upon a particular networking or communications medium. In its current incarnation, it utilizes XML and web services over IP networks, but the more important aspect of OpenADR are the semantic data models. There is nothing, in principle, preventing those data models being moved over to some other networking means as long as the full model and semantics of the information are retained.

Because OpenADR focuses on a specific application domain and has a proven track record in commercial and industrial facilities, it does a good job of capturing the requirements for automating DR and thus creating a data model for both dynamic prices and reliable DR that satisfies those requirements. There have been some preliminary efforts by Electric Power Research Institute (EPRI) to incorporate some of the features of OpenADR into IEC 61850, but that effort has not yet extended to the most important OpenADR data elements which comprise the message exchanges between the Utility/ISO and their customers.

First and foremost, OpenADR is a set of data models and interaction specifications that provide a means for utilities/ISO's to publish grid condition information, such as electricity prices, shed levels and grid reliability signals. The purpose of publishing the information using OpenADR is to affect some sort of automated change in end-use load profiles (i.e., Demand Response). The information is published using a standardized OpenADR message that is transmitted from the utility/ISO to various entities that may control end-use loads. Entities that receive and interpret these messages are said to "consume" OpenADR messages.

It is the specification of the OpenADR messages that are transmitted by the utility/ISO that are the most important aspects of OpenADR because it enables a multitude of vendors to build equipment that is capable of consuming OpenADR messages. OpenADR also supports non-repudiation of clients through client certificates.

This sort of interaction is squarely within the Smart Grid domain, and it is widely recognized that if entities can receive this type of information from the utilities/ISO's, there will be huge benefits to all parties concerned. This type of interaction allows freedom of choice for how end-loads are affected and stimulates greater creativity and innovation in the marketplace, which, in turn, leads to greater efficiencies on the grid. While the type of information in an OpenADR message, as expressed above, is somewhat general and could be used in a number of different ways, within the scope of OpenADR the intention is to use this information to automate the control of end-loads. Upon examination of the details of the OpenADR data models, it can be seen that there have been steps taken to facilitate the reception and processing of the information by automation equipment.

OpenADR is a key example of the Interoperability Standards effort led by NIST. Ed Koch, CTO of Akuacom, was the chair of the working group at LBNL that drafted the original specification for OpenADR at LBNL. He is currently co-chair of the UCAlug OpenADR taskforce and is directly involved with the NIST Roadmap and the OASIS technical committee.

Another key measure of this projects compatibility with the Energy Independence and Security Act of 2007 was to consider it in the context of the National Institute of Standards and Technology (NIST) Interoperability Roadmap. The CPP system integrated with this project utilizes the OpenADR standard, which has been identified by NIST in the Smart Grid Roadmap as a candidate for adoption to serve as the national standard. This system leverages a wide range of technology that is under consideration by the NIST Building to Grid Domain Expert Working Group. Through participation in working groups, members of this team also have input to NIST's Cyber Security Work Group.

Another important discussion regarding interoperability is to show how this project qualifies as one that is implementing Smart Grid Functions as outlined in the Energy Independence and Security Act of 2007 Section 1306(d).

SERVER STANDARDS

The DRAS server is built as a web service and utilizes standard components in its architecture. The physical servers are Dell PowerEdge Servers with Quad Core Xeon 64 bit processors. The storage are iSCSI appliances with RAID configuration, with dual power supplies and redundant Network connections. The operating system is Red Hat Linux 5 with VMWare Virtualization infrastructure. We have implemented the Web tier with physical servers running Apache 2.2. There is a Checkpoint firewall and a separate internal network between the web servers and the Application Server. The application server utilizes Jboss 4.2.3 J2EE Application Server and a MySQL database server.

All these off the shelf components cab and are used within the industry to build secure enterprise applications. We chose this technology set because of its wide implementation in the industry.

SECURITY PROCESS

The following describes the various processes that are being employed to address Cyber Security.

DRAS PROCESS INFRASTRUCTURE

DRAS LOG

DRAS generates system logs as well as application log report. Web server and application server log a variety of program events, application software debug and status information, and system error messages. System logs have default rollup and purge mechanisms: both sets of logs are rolled every week, and logs older than a week are automatically purged. The rollup and purge mechanisms are all configurable in each layer. DRAS application log are maintained in “firelog” DB. DRAS Operator User site provides “Log Report” Interface for the application log. You can run a query to generate filtered reports for various DRAS application activities and program events. The log report can be exported to csv format. The log tables can grow very large. To ensure that these files and tables do not consume all available disk space, DRAS has tool to periodically monitor, backup, and purge them.

SYSTEM AND DATA BACKUP AND RESTORE

To ensure the availability of the DRAS, DRAS database is automatically backed up via a cron job that runs daily at 1:30 AM. However, in the unlikely event of a multi-point failure, you may need to manually back up or restore the DRAS database.

DRAS application is stateless and does not contain any DRAS application data in Apache Web Server and JBoss Application Server. All Servers are being deployed from templates from which any failed server can be re-deployed in a short period of time. Combined with the regular database backups this allows for a fast and reliable system recovery in case of a catastrophic system failure or other disaster.

CHANGE CONTROL PROCESS

Any releases to production go through a QA and staging process. After a release passes both stages will it is considered ready for production. The product manager will then communicate the availability to the customer and set the actual deploy date.

SYSTEM DIAGNOSTIC AND RECOVER PROCESS

Akuacom utilizes the SolarWinds software package for diagnostics. SolarWinds monitors all components including hardware infrastructure and prints out graphs and tables with the performance data. SolarWinds web-based UI displays diagnostic information about each of the subsystems and send alerts to Akuacom if abnormal situation arise in the infrastructure. Examples include disk filling up, excessive dropped packets, increased CPU load on subsystem.

If an error condition occurs in the application or in the infrastructure, Akuacom will be notified via alert or operator. Akuacom can diagnose the situation from the SolarWinds web panel and login to the specific troubled subsystem to further diagnose the situation and apply the fixes.

DRAS PHYSICAL SECURITY

PHYSICAL SECURITY CONTROL PROCESS

The hosting facility is SAS70 certified and the following features are part of the security implementation:

- CCTV surveillance throughout the facility
- Advanced access control, alarm monitoring, digital video, and intrusion detection Hardened exterior (bullet-resistant glass and walls)
- Access requires pre-authorization by a trusted customer representative (Primary Contact)
- 24x7x365 Security-controlled data center access

- All cabinets, cages, and suites are secured - security upgrades available
- One main entry point with security personnel present to verify identification
- Access logs available upon request
- Badge Policy (valid government issued photo ID requirement)

The hosting facility has deployed Lenel OnGuard – a state-of-the-art access control system which provides access control, alarm monitoring, digital video, and intrusion detection that delivers a single, seamlessly integrated solution for monitoring and recording data center activity. Security is staffed by trained, professional Security Officers 24x7x365.Access.

QUALITY ASSURANCE

To support the quality assurance process, Akuacom utilizes two parallel servers which are configured exactly the same as the configuration server. Software modules are first unit tested on the developer's workstations. Once the code has gone through a unit check, it is checked into the central source repository. The latest code line is sent through a automated check nightly to confirm that based unit tests continue to work as new code is checked-in. This often identifies side effects of new modules very early in the process.

Releases are periodically put onto the internal test server. A DNS entry is created and the testing runs through the entire production infrastructure. A full test script is run on the internal test server before it is approved for release. New releases are placed on a second staging server that is available to the customer for acceptance. When final approval is given by the customer, then the code is moved to the production server.

Test servers are set so that emails will not be sent to external addresses. This allows us to import production accounts into the test server and not impact customers. This is necessary to fully test database conversion scripts. Test servers remain in the collocation facility and they enjoy the same physical and cyber protections as the production servers.

All issues discovered in the QA process are tracked in a bug tracking database and each bug is given a priority and the release will not go into production with any priority one bugs or priority 2 bugs that don't have workarounds.

As part of the QA process, the core operating software for the server components are continuously upgraded when security patches from the vendors of this equipment become available. All of Akuacom's equipment and third party software is registered with the vendor it was purchased from so that when updates do become available from the vendor Akuacom is notified immediately. When security patches become available they are immediately evaluated and the upgrades are scheduled at the earliest possible time.

In conclusion, the founders of Akuacom have a long and successful history of developing communication architectures and applications for the utility industry that are targeted towards integrating automation systems and devices in facilities with enterprise applications. They have a deep and broad understanding of the systems and devices that may exist in facilities. For many years they have worked closely with a wide range of control vendors, including chairing and drafting key communications standards for the control industry. They have also worked closely with a variety of utilities in developing enterprise applications that may need to communicate with control systems and devices. This unique experience, and expertise with both the utilities IT requirements and the facility control industry, has enabled them to provide technology and services for AutoDR where highly secure communications by a utility with a potentially large number of devices and systems is crucial.

ROLES AND RESPONSIBILITIES

The following roles are established to manage the security of the system.

Cyber Security Program Sponsor – Clay Collier, Chief Executive Officer, Akuacom

This individual has the overall responsibility and accountability for the cyber security program providing any necessary resources required for its development, implementation, or sustenance.

Cyber Security Program Manager – Paul Lipkin, Director of Operations, Akuacom

The individual serving within this role has multiple responsibilities that include:

- providing oversight of the plant cyber security operations by interfacing and insuring that the co-location facilities are meeting their contractual obligations to provide plant level security
- functioning as the single point of contact for all issues related to cyber security
- initiates and coordinates cyber security incident response team (CSIRT) functions as required
- coordinates with regulatory, compliance, legal, local/regional/national authorities as required relate to cyber security events
- ensures and approves the development and operation of the cyber security education, awareness, and training programs

- oversees and approves the development and implementation of cyber security policies and procedures

Cyber Security Specialists – Liz Jones, Director of Engineering, Akuacom; Thorsten Bach Program Manager, Akuacom

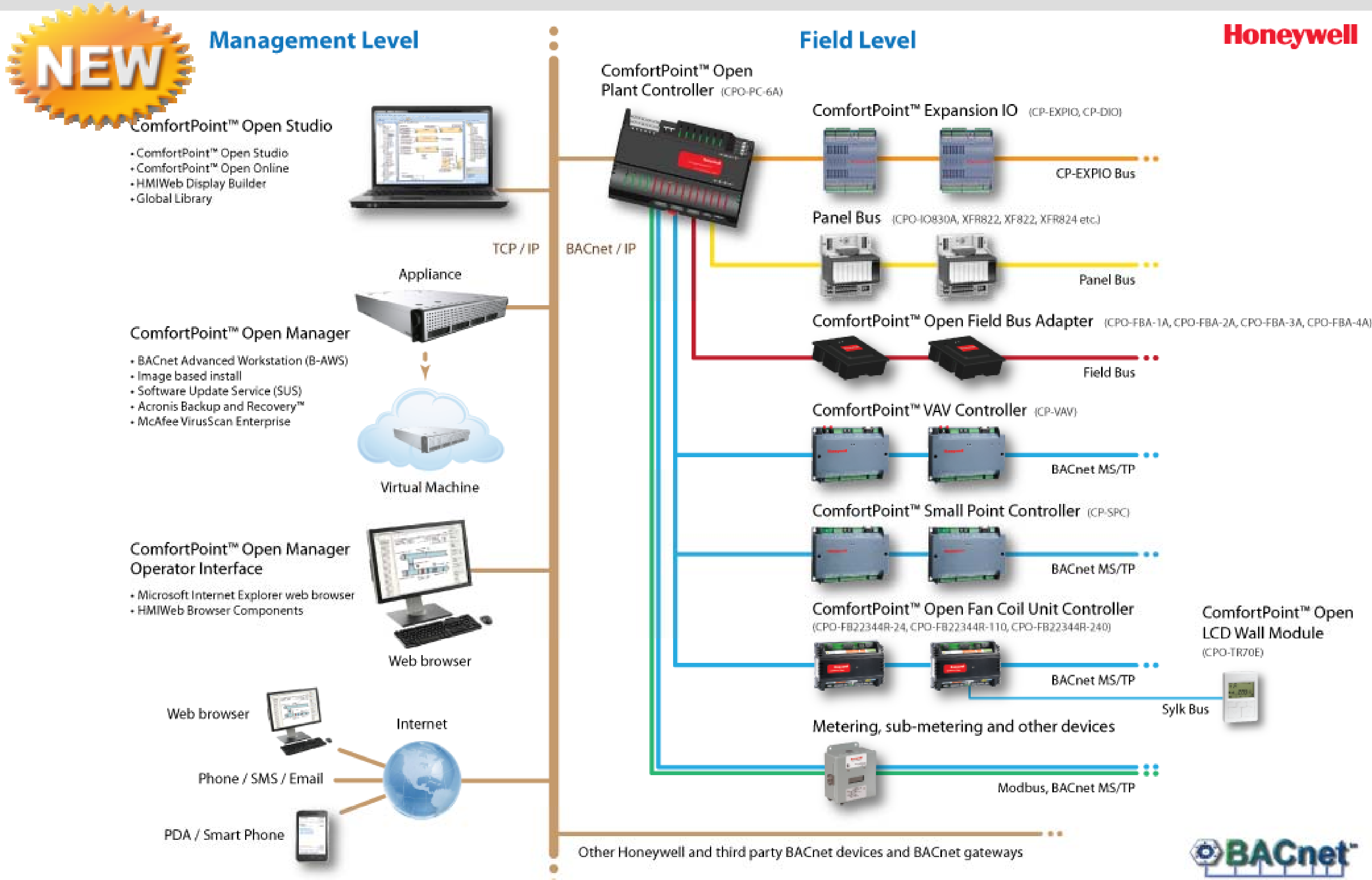
Both individuals have cyber security expertise and applies it to the development of various aspects of the systems used by Akuacom to insure that they are developed in a manner that supports the cyber security requirements. Their responsibilities include:

- protect critical systems from cyber threat
- understand the cyber security implications surrounding the overall architecture of facility networks, operating systems, hardware platforms, and facility-specific applications, and the services and protocols upon which those applications rely
- perform cyber security evaluations of digital plant systems
- conduct security audits, network scans, and penetration tests against critical systems as necessary
- conduct cyber security investigations involving compromise of critical systems
- preserve evidence collected during cyber security investigations to prevent loss of evidentiary value
- maintain expert skill and knowledge level in the area of cyber security
- acts as the primary director or leader in a CSIRT, reporting to the Cyber Security Program Manager (Thorsten Bach)

The Cyber Security Incident Response Team (CSIRT) is comprised of Paul Lipkin and Liz Jones, who also manage teams of engineers and technicians that can adequately address any issue that may arise on an as needed basis when a security event is declared.

Appendix B: Equipment Cut Sheets

HBS ComfortPoint™ Open / It's a Complete "System"



Highlights of the Offering

- **ComfortPoint™ Open Manager / User Interface**
  - ✓ Organized workflow for building operator (HVAC / Energy) + consistent Image and results
  - ✓ Quick access to system information ➔status ➔ trends ➔ reports
  - ✓ Building Control + <u>Energy integration</u>
  - ✓ Automated display generation – links to trends and reports
  - ✓ Stationary Browser (workstation) and Zero footprint Mobility (PDA) client options
- **ComfortPoint Open Tool Studio**
  - ✓ One tool and out of the box configured
  - ✓ Tested Library – consistency of sequences from Library
  - ✓ Proven Standards ensure quality installs
  - ✓ Subcontractor Commissioning tool via web
  - ✓ Navigation - object based work space
- **Hardware**
  - ✓ BACnet Listed (B-AAC), (B-AWS pending)
  - ✓ IP connected
  - ✓ Field Bus adapter – less wire smaller conduit
  - ✓ Ability to connect to metering
  - ✓ UUKL*

* Approval in process , 2012

Honeywell

ComfortPoint Open

CPO-PC-6A PLANT CONTROLLER

PRODUCT DATA

GENERAL

The ComfortPoint™ Open Plant Controller CPO-PC-6A is an independently mounted electronic control unit which is designed for a wide variety of complex applications in residential, commercial, and light-industrial environments.

The CPO-PC-6A features a large complement of different analog inputs, analog outputs, binary inputs, binary outputs, and relays.

The CPO-PC-6A also features numerous communication interfaces, chief among them four different RS485 interfaces (three of which are screw-type terminals located in the terminal block at the upper left-hand corner; the fourth consists of push-in terminals at the upper right-hand corner). It also possesses two standard Ethernet interfaces.

The CPO-PC-6A is thus compatible with a wide range of other electronic devices (see also Fig. 1. ComfortPoint™ Open System architecture on pg. 2).

Clearly visible LED control lamps convey important status and alarm information.

The CPO-PC-6A has a durable, anthracite-colored plastic housing conforming with DIN 43880, with a max. slot height of 45 mm. It is thus suitable for mounting in fuse boxes, but can also be mounted on 35 mm standard panel rails (both vertical and horizontal mounting possible).

FEATURES

- **24 Vac/dc power supply (from external transformer).**
- **Three separate RS485 interfaces consisting of screw-type terminals.**
- **One additional RS485 interface consisting of push-in terminals.**
- **Three pairs of LEDs indicating the transmission and reception (respectively) of data via the three screw-type RS485 interfaces.**
- **Quick and convenient connection to neighboring modules using the XS816 Bridge Connector (regular cabling also possible).**
- **Alarm LED, power LED.**
- **Three DIP switches for manually switching internal biasing resistors to the three screw-type RS485 interfaces.**
- **Two Ethernet connectors and corresponding status LEDs.**
- **Watchdog (terminals 9 and 10 in the block of screw-type terminals at the upper left-hand corner) for connection to optical or acoustical signaling devices.**
- **Communication using the Panel Bus communication protocol (all four RS485 interfaces), the BACnet MS/TP protocol (RS485 interfaces 1, 2, and 3), the Field Bus protocol (RS485 interfaces 1, 2, and 3), the Modbus protocol (RS485 interfaces 1, 2, and 3), and the IPC I/O protocol (RS485 interface 4, only).**
- **Built-in advanced diagnostics software facilitating troubleshooting.**

CE

DESCRIPTION

The ComfortPoint™ Open System consists of the CPO-PC-6A Plant Controller and other field-level devices as well as management-level systems connected via the controller's various interfaces and bus connections. See also Fig. 1.

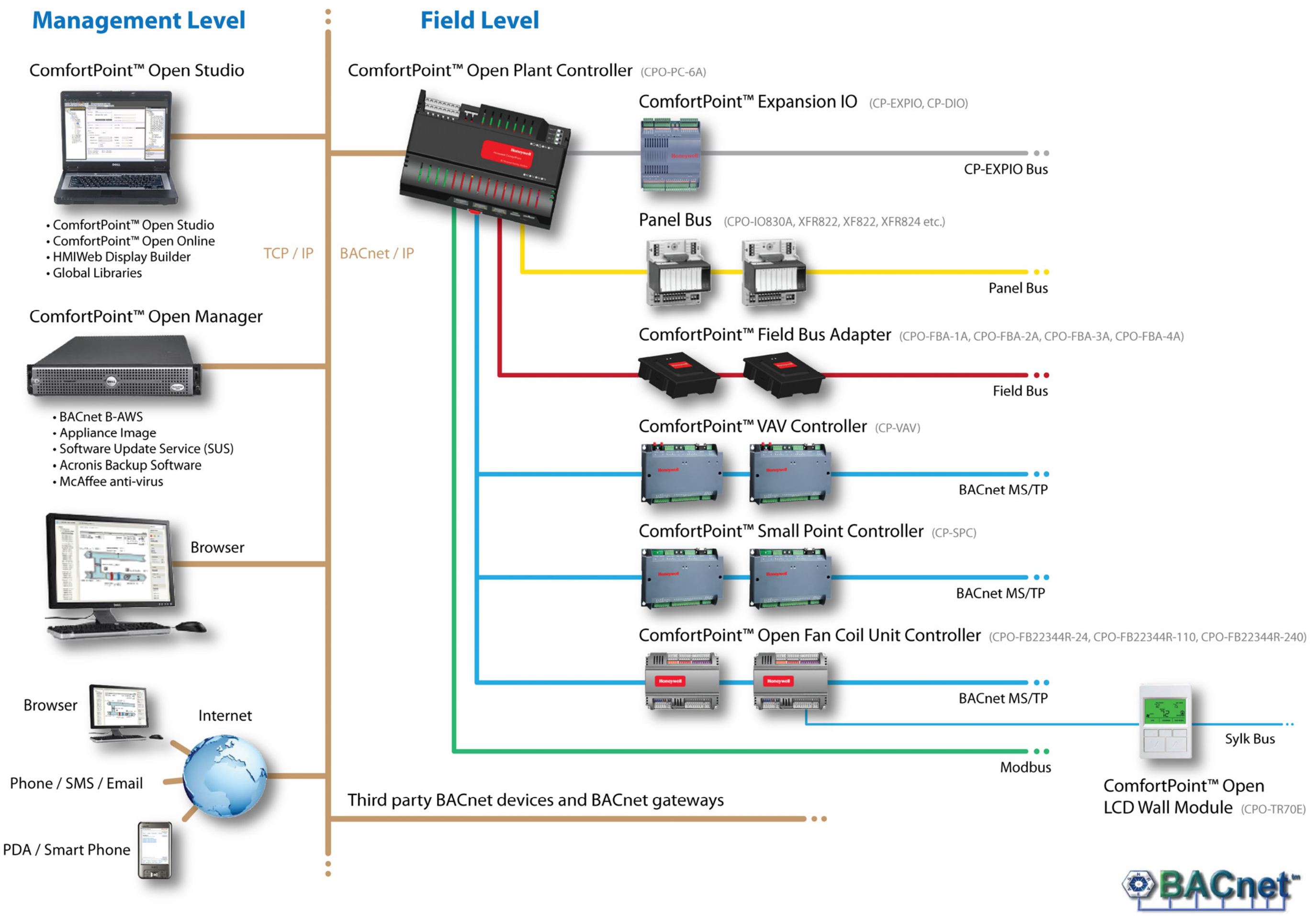


Fig. 1. ComfortPoint™ Open System architecture

INTERFACES AND TERMINALS

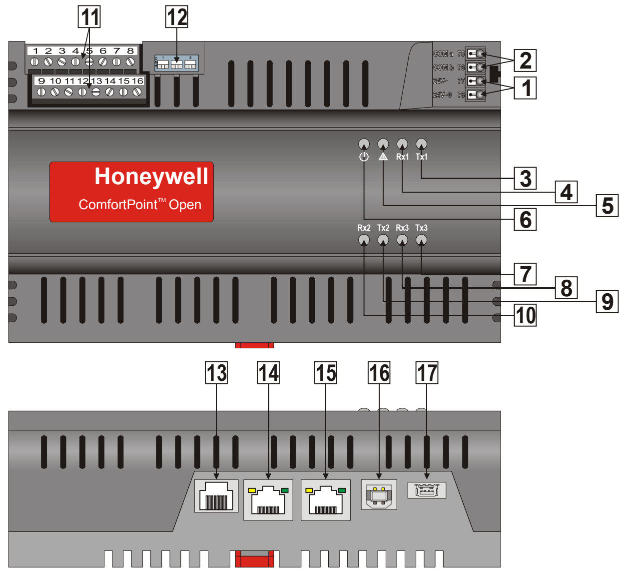


Fig. 2. Interfaces and terminals

Legend

1 Power supply for I/O modules
2 Panel Bus communication terminals
3 Tx 1 LED (yellow)
4 Rx 1 LED (yellow)
5 Alarm LED (red)
6 Power LED (green)
7 Tx 3 LED (yellow)
8 Rx 3 LED (yellow)
9 Tx 2 LED (yellow)
10 Rx 2 LED (yellow)
11 two terminal blocks, incl. terminals 1-16
12 DIP switches for individually setting RS485 buses
13 RS232 interface
14 Ethernet 1 connector
15 Ethernet 2 connector
16 USB-B connector (not used)
17 USB-A connector (not used)

CPO-PC-6A Terminals

Table 1. Description of CPO-PC-6A terminals

Type	Term.	Signal	Comment
SCREW-TYPE TERMINALS	1	24 V~	power supply (24 Vac/dc) from transformer (internal connection to terminal 77)
	2	24 V~0	power supply (24 Vac) from transformer (internal connection to terminal 78)
	3		(+) for RS485 interface 1
	4		(-) for RS485 interface 1
	5		(GND) for RS485 interface 1
	6		(GND) for RS485 interface 4
	7		not used.
	8		not used.
	9		watchdog relay
	10		watchdog relay
	11		(+) for RS485 interface 2
	12		(-) for RS485 interface 2
	13		(GND) for RS485 interface 2
	14		(+) for RS485 interface 3
	15		(-) for RS485 interface 3
	16		(GND) for RS485 interface 3
PUSH-IN TERMINALS	75	COM a	(+) for RS485 interface 4
	76	COM b	(-) for RS485 interface 4
	77	24 V~	power supply for connected modules
	78	24 V~0	power supply for connected modules

NOTICE

Equipment damage!

► Make sure that the CPO-PC-6A is not connected to earth ground.

► If nonetheless earth grounding is required, make sure that only terminal 2 is connected to earth ground. Terminal 1 must not be connected to earth ground.

Tx LED and Rx LED

The CPO-PC-6A is equipped with three Tx LEDs (status: yellow/OFF) and three corresponding Rx LEDs (status: yellow/OFF).

These LEDs indicate (by flickering) the transmission / reception of data by the CPO-PC-6A via its three RS485 interfaces.

Specifically:

- Tx1 and Rx1 indicate the transmission/reception (respectively) of data by the CPO-PC-6A via its RS485 interfaces 1 (Bus 1: terminals 3, 4, and 5).
- Tx2 and Rx2 indicate the transmission/reception (respectively) of data by the CPO-PC-6A via its RS485 interfaces 2 (Bus 2: terminals 11, 12, and 13).
- Tx3 and Rx3 indicate the transmission/reception (respectively) of data by the CPO-PC-6A via its RS485 interfaces 3 (Bus 3: terminals 14, 15, and 16).

Table 2. Behavior and meaning of RS485 LEDs

LED behavior	meaning
OFF	No communication over the given RS485 interface.
ON steadily	Fault.
ON/OFF randomly	Communication occurring over the given RS485 interface.

RS232 Interface

The CPO-PC-6A is equipped with an RS232 Interface for the connection of HMIs, e.g., a PC or a laptop (on which either the ComfortPoint Online Tool or ComfortPoint Open Studio has been installed) via a standard XW885 cable (or, alternately, a XW585 cable connected with an XW586 cable).

Ethernet 1 Interface

RJ45 female interface for permanent connection to the ETHERNET network.

Ethernet 2 Interface

For connection of a laptop or PC (onto which ComfortPoint Open Studio has been installed) via a standard Ethernet cross-over cable for application download/upload, or application de-bugging, or Internet Browser access, while the CPO-PC-6A can remain connected in the Ethernet network without interruption. This allows parallel access, e.g., without creating alarm showers at the front-end.

USB Interfaces

USB-A and USB-B interfaces are currently without use.

Alarm and Power LEDs

The CPO-PC-6A is equipped with an alarm LED and a power LED.

Alarm LED (red)

The alarm LED indicates the status of the watchdog relay (terminals 9 and 10). The watchdog relay is for connection to optical or acoustical signals, and allows 24 V, 500 mA dry contacts. These contacts are closed when the power is OFF, when no application is loaded, or when the firmware or application is not working properly. The watchdog resets the CPO-PC-6A if the delay since the previous trigger exceeds 20 sec. Further, the watchdog locks the CPO-PC-6A if the trigger between two restarts is not set.

NOTE: In the event of software problems, the CPO-PC-6A should be restarted by switching the power OFF and then back ON.

Table 3. Alarm LED

behavior	meaning
OFF	Watchdog alarm relay contacts are open = normal operation (or unpowered).
ON	Watchdog alarm relay contacts are closed = failure (alarm) status. • CPO-PC-6A has encountered a hardware problem. • The application has a fault. • CPO-PC-6A powered up without application or operator has manually stopped application, e.g., using the ComfortPoint Online Tool. The LED will then light up 13 min. after power-up without application.

Table 4. Permissible load of terminals 9, 10

	max. load	min. current
per normally closed contact (terminals 9, 10)	**19…29 Vac** current at cos φ ≥ 0.95: 0.5 A, current at cos φ ≥ 0.6: 0.5 A **19…29 Vdc** 0.5 A resistive or inductive	10 mA

Power LED (green)

Table 5. Power LED

behavior	meaning
ON	Normal operation. CPO-PC-6A is in Boot loader mode. Either Boot loader 1 or Boot loader 2 is running.
OFF	No power to processor, LED damaged, low voltage to board, first second of power up, or boot loader damaged or NAND flash formatting is in process.
very slow blink	CPO-PC-6A is operating normally and the firmware is executing the application.
slow blink	Firmware is not executing application.

DIP Switches

The CPO-PC-6A features three DIP switches (equipped with 510 Ω bias resistors) located to the right of the two blocks of non-removable screw-type terminals. Each DIP switch can be used to switch the 510 Ω bias resistor of the corresponding RS485 interface ON and OFF.

- The bias resistor of RS485 interface 1 (terminals 3, 4, and 5) is switched ON/OFF using DIP switch 1.
- The bias resistor of RS485 interface 2 (terminals 11, 12, and 13) is switched ON/OFF using DIP switch 2.
- The bias resistor of RS485 interface 3 (terminals 14, 15, and 16) is switched ON/OFF using DIP switch 3.

The resultant communication rate over RS485 interfaces 1, 2, and 3 depends upon the given communication protocol selected during engineering using ComfortPoint Open Studio.

MEMORY

Table 6. CPO-PC-6A memory

Memory	Size
SRAM	512 KB
NOR-Flash	4 MB
NAND-Flash	512 MB
Clock-time	Freescale Coldfire MCF5485, 200 MHz, 32-bit

NOTE: The CPO-PC-6A does not contain a battery. The contents of RAM (incl. online data [out-of-service flag and runtime datapoint properties] and real-time clock time) are buffered by a super capacitor for (typically) 72 hours.

Serial number, date code, part number, and manufacturing location are stored in the CPO-PC-6A non-volatile memory and are thus protected against deleting or overwriting.

GENERAL SAFETY INFORMATION

- ► When performing any work (installation, mounting, start-up), all manufacturer instructions and in particular the Installation and Commissioning Instructions (EN1B-0462GE51) are to be observed.
- ► The ComfortPoint^{TM} Open System (including the CPO-PC-6A Plant Controller, Panel Bus I/O modules, manual disconnect modules, and the auxiliary terminal packages) may be installed and mounted only by authorized and trained personnel.
- ► Rules regarding electrostatic discharge should be followed.
- ► If the ComfortPoint^{TM} Open System is modified in any way, except by the manufacturer, all warranties concerning operation and safety are invalidated.
- ► FCC-CERTIFIED: This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.
- ► Make sure that the local standards and regulations are observed at all times. Examples of such regulations are VDE 0800 and VDE 0100 or EN 60204-1 for earth grounding.
- ► Use only accessory equipment which comes from or has been approved by Honeywell.
- ► It is recommended that devices be kept at room temperature for at least 24 hours before applying power. This is to allow any condensation resulting from low shipping/storage temperatures to evaporate.
- ► The ComfortPoint Open System must be installed in a manner (e.g., in a lockable cabinet) ensuring that uncertified persons have no access to the terminals.
- ► Investigated according to United States Standard UL-60730.
- ► Investigated according to Canadian National Standard(s) C22.2, No. 205-M1983 (CNL-listed).
- ► Do not open the CPO-PC-6A, as it contains no user-serviceable parts inside!
- ► CE declarations according to LVD Directive EEC/2006/95 and EMC Directive EEC/2004/108.
- ► Product standards are EN 60730-1 and EN 60730-2-9.

Safety Information as per EN60730-1

The ComfortPoint Open System is intended for residential, commercial, and light-industrial environments.

The ComfortPoint Open System is an independently mounted electronic control system with fixed wiring.

The CPO-PC-6A is suitable for mounting in fuse boxes conforming with standard DIN43880, and having a slot height of max. 45 mm.

It is suitable for panel rail mounting on 35 mm standard panel rail (both horizontal and vertical rail mounting possible).

The CPO-PC-6A is used for the purpose of building HVAC control and is suitable for use only in non-safety controls for installation on or in appliances.

Table 7. Safety information as per EN60730-1

Shock protection	24 V-powered controls: Class III mains-powered controls: Class II
Pollution degree	Pollution Degree 2, suitable for use in home and industrial environments.
Installation	Class 3
Overvoltage category	24 V-powered controls: Category I mains-powered controls: Category II
Rated impulse voltage	330 Vac for Category I 2500 Vac for Category II
Automatic action	Type 1.C (micro-interruption for the relay outputs)
Software class	Class A
Enclosure	IP20 according to EN-60529
Ball-pressure test temperature	75 °C for all housing and plastic parts 125 °C in the case of devices applied with voltage-carrying parts and connectors
Electromagnetic interference	Tested at 230 Vac, with the modules in normal condition.
System transformer	Europe: safety isolating transformers according to IEC61558-2-6 U.S.A. and Canada: NEC Class-2 transformers

TECHNICAL DATA

System Data

Table 8. System data

operating voltage	24 Vac, ± 20% (50/60 Hz), 21 … 30 Vdc
power consumption	max.: 7 VA; min.: 6 VA; typical: 6 VA
push-in terminals	1.5 mm^2
screw-type terminals	2.5 mm^2
overvoltage protection	All screw / push-in terminals not having a dedicated connector are protected against overvoltages of max. 28.8 Vac (50/60 Hz) or 40.8 Vdc (24 Vac +20%). All screw / push-in ***output*** terminals are protected against short-circuiting.

Standards

Table 9. Standards

protection class	IP20
product standard EMC	EN 60730-1 EN 60730-2-9
testing electrical components	IEC68
certification	CE, UL
system transformer	The system transformer(s) must be safety isolating transformers according to IEC 61558-2-6. In the U.S.A. and Canada, NEC Class 2 transformers must be used.
Low-Voltage Device Safety Assessment	EN 60730-1 EN 60730-2-9

Operational Environment

Table 10. Operational environment

ambient operating temperature	0 … 50 °C (32 … 122 °F)
ambient operating humidity	5 … 95% relative humidity (non-condensing)
vibration under operation	0.024” double amplitude (2 … 30 Hz), 0.6 g (30 … 300 Hz)
dust, vibration	According to EN60730-1
RFI, EMI	residential (home), commercial, and light-industrial environments

Interfaces and Bus Connections

Via its various interfaces and bus connections, the CPO-PC-6A can be connected to a variety of devices and systems.

Supported Communication Protocols

The following communication protocols are supported. (There are no limitations pertaining to the parallel / concurrent use of communication protocols.) See Table 11.

Table 11. Protocols supported by communication interfaces

communication interface	supported protocol(s)
Panel Bus (terminals 75, 76)	Panel Bus; IPC I/O
RS485 interface 1 (term. 3, 4, 5)	Panel Bus, BACnet MS/TP, Mod-Bus, Field Bus
RS485 interface 2 (term. 11, 12, 13)	
RS485 interface 3 (term. 14, 15, 16)	
watchdog (terminals 9, 10)	--
RS232 interface	--
Ethernet 1 interface	BACnet/IP, Telnet
Ethernet 2 interface	BACnet/IP, Telnet
USB-A, USB-B interfaces	not used

The communication rate across each communication interface is dependent upon the given communication protocol.

DIMENSIONS

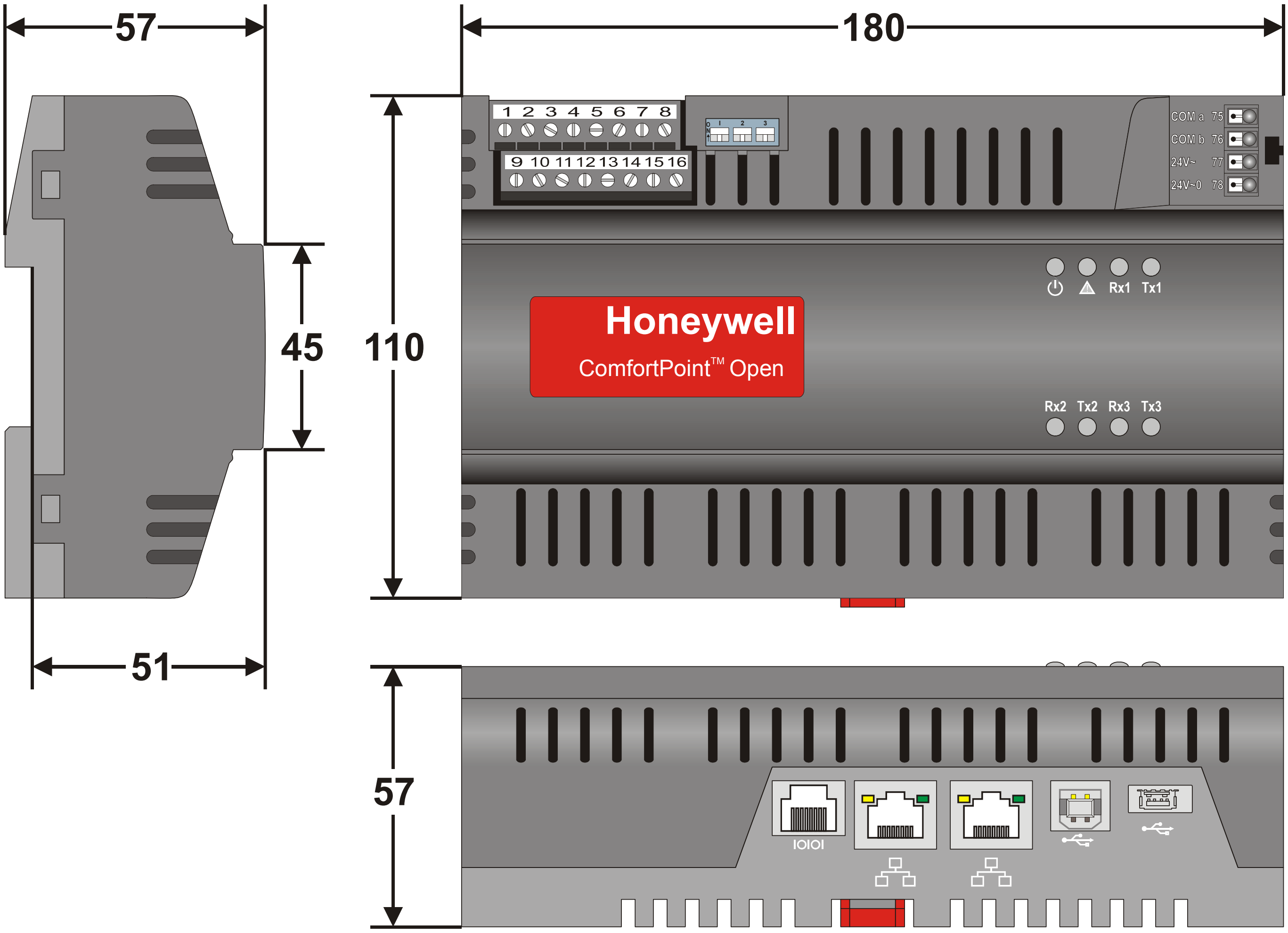


Fig. 3. CPO-PC-6A dimensions (mm)

Honeywell

Manufactured for and on behalf of the Environmental and Combustion Controls Division of Honeywell Technologies Sàrl, Rolle, Z.A. La Pièce 16, Switzerland by its Authorized Representative:

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Subject to change without notice. Printed in Germany

EN0B-0656GE51 R0212

JACE®-602-XPR-24

Overview

Tridium's JACE (Java Application Control Engine), JACE-602-XPR-24 is an embedded controller/server platform designed for remote monitoring and control applications. The unit combines integrated control, supervision, data logging, alarming, scheduling and network management functions, integrated IO with Internet connectivity and web serving capabilities in a small, compact platform. The JACE-602-XPR-24 makes it possible to control and manage external devices over the Internet and present real time information to users in web-based graphical views.

The JACE-602-XPR-24 is part of the Tridium portfolio of Java-based controller/server products, software applications and tools, designed to integrate a variety of devices and protocols into unified, distributed systems. Tridium products are powered by the Niagara^{AX} Framework®, the industry's leading software technology that integrates diverse systems and devices into a seamless system. Niagara^{AX} supports a range of protocols including LonWorks®, BACnet®, Modbus, oBIX and many Internet standards. The Niagara^{AX} Framework also includes integrated management tools to support the design, configuration and maintenance of a unified, real-time controls network. The integral IO, enclosure and low voltage input power supply, make this platform ideal for fast track (XPRress) projects.

Applications

The JACE-602-XPR-24 is ideal for smaller facilities, remote sites, and for distributing control and monitoring throughout large facilities. It is also ideal for managing and controlling today's energy applications. On-board inputs and outputs are available for applications where local control is required. The JACE-602-XPR-24 supports a wide range of field busses for connection to remote I/O and stand-alone controllers. In small facility applications, the JACE-602-XPR-24 is all you need for a complete system. The JACE-602-XPR-24 serves data and rich graphical displays to a standard web browser via an Ethernet LAN or remotely over the Internet. In larger facilities, multi-building applications and large-scale control system integrations, AX Supervisor™ software can be used to aggregate information (real-time data, history, alarms, etc.) from large numbers of JACEs into a single unified application. The Tridium AX Supervisor can manage global control functions, support data passing over multiple networks, connect to enterprise level software applications, and host multiple, simultaneous client workstations connected over the local network, the Internet, or dial-up modem.

This JACE also comes with a built-in GPRS modem option for remote access via the cellular network with service provided by Wyless. Various service plans are available from Wyless depending on the amount of data needed to be passed on a monthly basis. In addition, an optional GPRS modem card is available to allow installation in the field if it was not initially purchased with the JACE-XPR. This option card will occupy the one communication card socket on this JACE platform.

Features

- Embedded Power PC platform @ 524 MHz
- Supports open and legacy protocols
- Web User interface serves rich presentations and live data to any browser
- Run stand-alone control, energy management, and multi-protocol integration
- BTL® listed when BACnet driver is used – complies with B-BC (BACnet Building Controller)
- Communications board socket for optional communications card
- Compact wall-mount design for easy installation
- Built-in 24 volt AC/DC power supply
- Onboard 16 point I/O
- Integral GPRS modem with Wyless SIM available for remote access via Wyless ISP service

Ordering Information

Part Number	Description
T-602-XPR-24	Base Unit including two Ethernet ports, one RS-232 port, and one RS-485 port, 8 universal inputs, 4 digital outputs, 4 analog outputs, 24 volt AC/DC input power supply
T-602-XPR-24GW	Base Unit including two Ethernet ports, one RS-232 port, and one RS-485 port, 8 universal inputs, 4 digital outputs, 4 analog outputs, 24 volt AC/DC input power supply, integral GPRS modem with Wyless SIM

Specifications

Platform

- AMCC PowerPC 440 @ 524 MHz processor with math coprocessor
- 256 MB SDRAM & 128 MB Serial Flash
- Battery Backup
- Real-time clock

Communications

- 2 Ethernet Ports – 10/100 Mbps (RJ-45 Connectors)
- 1 RS 232 Port (RJ-45 connector)
- 1 RS 485 non isolated port (Screw Connector on base board)
- 1 socket for optional communication cards
- 1 USB port (future use)

Optional Communications Cards

Part Number	Description
NPB-LON	Optional 78 Kbps FTT10 Compatible Lon Adapter
NPB-232	Optional RS-232 port adapter with 9 pin D-shell connector
NPB-2X-485	Optional dual port RS-485 adapter; electronically isolated
NPB-MDM	Optional 56 Kpbs Auto-dial/Auto-answer Model
T-GPRS-XPR	GPRS Modem retrofit kit for JACE-XPR platforms, uses one option card slot. this is for JACE-XPRs purchased without the internal GPRS modem. Includes a Wyless SIM and a remote mount antenna with mounting bracket

Serial Port Connector Accessories

Part Number	Description
10148	RJ-45 to 9 pin D-shell adapter for use with connector on the base board for RS-232 Serial connections; use of one of the following cables to extend the connection from the T-602-XPR-24
10180	4 foot (1.22 meters) RJ-45 cable for use with the 10148 adapter
10181	10 foot (3.05 meters) RJ-45 cable for use with the 10148 adapter
10182	25 foot (7.62 meters) RJ-45 cable for use with the 10148 adapter

Operating System

- QNX RTOS, IBM J9 JVM Java Virtual Machine
- Niagara^{AX} Release 3.4 or later

Onboard I/O

- 8 Universal Inputs (0-100K ohm, 0-10 volts, 0-20 MA with external resistor , or 10K type 3 thermistor)
- 4 relay outputs (Form A contacts, 24 VAC @.5 amp rated)
- 4 analog outputs (0-10 volt DC)
- All IO terminated via removable screw terminal blocks for easy installation

I/O Specification

- Removable screw terminals (.2" centers) for all inputs and outputs (in blocks of 6 or more screws)
- Universal Input types supported:
  - Type 3 (10K) Thermistors; Thermistor Sensor Range –23.3°C to +115.5°C (–10° to +240° F). Input accuracy is in the range of +/-1% of span. Others may be supported by entering custom non-linear curve interpolation points for each unique non-linear input
  - 0 to 10 volt; accuracy is +/- 2% of span, without user calibration
  - 4-20 mA current loop; accuracy is +/- 2% of span, without user calibration; Self-powered or board-powered sensors accepted; uses an external resistor for current input (four provided, mounted by installer on input terminal connections
  - Dry contact; 3.3 volt open circuit, 300-uA short-circuit current
  - Pulsing dry contact at a rate of up to 20 Hz; 50% duty cycle
- Digital Outputs (4 ea) Pilot Duty
  - Form A relay contacts suitable for on / off control only; floating control not supported
  - Max voltage - 30 volts DC or AC
  - ½ Amp max current rating for each contact
- Analog Outputs (4 ea)
  - 0 - 10 Volt DC

Power Input

- 24 Volts AC or DC, 40 Watts Max
- Screw terminal connection

Battery Backup

- Battery Backup - 5 minutes typical - shutdown/database backup begins within 10 seconds of power failure
- Real-time clock - 3 month backup min via battery

Dimensions

- 12 5/8" (320.7 mm) L x 7 1/2" (190.5mm) W x 2 1/4" (57.2mm) H
- Weight: 2.5 lbs (1.13 Kg) net; 3.5 lbs (1.59 Kg) gross

Chassis - Housed in molded plastic enclosure

- Construction: Plastic, screw mount chassis, plastic cover
- Cooling: Internal air convection
- Wiring access holes provided at top and bottom of case and via knockouts on base for hidden wiring

Environment

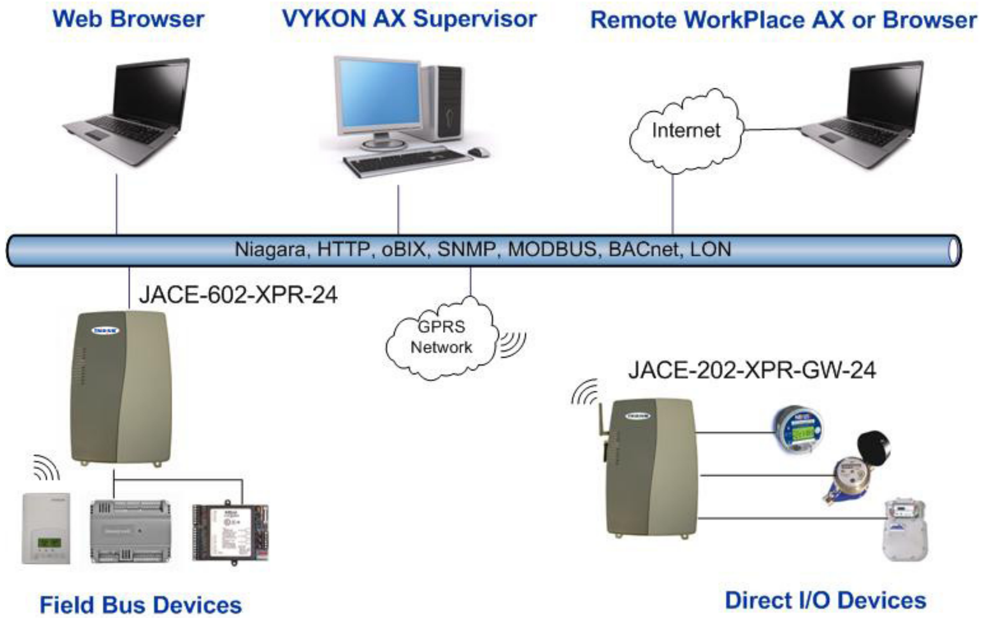
- Operating temperature range: 0° to 50° C (32° F to +122° F)
- Storage Temperature range: 0° to 70° C (32° F to +158° F)
- Relative humidity range: 5% to 95%, non-condensing

Agency Listings

- RoHS compliant RoHS Compliant
- UL 916, E207782 Energy Management
- C-UL listed to Canadian Standards Association (CSA) C22.2 No. 205-M1983 “Signal Equipment”
- FCC part 15 Class A
- BTL B-BC BACnet Building controller listed when the BACnet driver is installed and configured
- CE

EMS Standards Applied	Standard Description	Criteria Met
CISPR 16-2-3:2006	Radiated Emissions - Class A	Compliant
IEC 61000-4-2	Electrostatic Discharge Immunity	PASS Class B
IEC 61000-4-3	Radiated Electromagnetic Field Immunity	PASS Class A
IEC 61000-4-4	Electrical Fast Transient/Burst Immunity	PASS Class B
IEC 61000-4-6	Conducted Radio-Frequency Immunity	PASS Class A
IEC 61010-1	Safety requirement for electrical equipment for measurement, control and laboratory use	PASS

Architecture



Appendix C: Demonstration Site Summary

Office Building A

Site

Building Type	Commercial
Utility Service Classification	SC. 9 Large - General
Location	New York, NY
Gross Floor Area	1.6 Million ft^2 (Conditioned Area: 1.4 Million ft^2)
No. of Buildings, Floor	1 building, 32 floors
Building Program	Office
Occupancy Schedule	Mon-Fri, 6am - 6pm
Facility Management Type	Outsourced

Utility & Demand Response Programs

Energy Provider	NYPA - Electricity, Con Edison - Steam
Peak Load (kW)	6,192
Peak Load Intensity (W/m^2)	48
Load Factor	0.51
Annual Consumption (kWh)	27,611,976
Demand Response Program	NYISO SCR & EDRP
Curtailment Service Provider	Energy Curtailment Specialists, Inc.

HVAC System

Air Distribution Type	Constant air volume with multiple-zone reheat
Air Handler Unit	VSD
Cooling Plant	(3) 1,350-ton centrifugal chillers and (1) 900-ton centrifugal chiller
DDC Zone Control	Yes
Global Temperature Adjustment	No
Other System	Heating provided using steam

Lighting System

Zone Control	Multi-zone control
Centralized Control	No

Energy Management and Control System

EMCS Vendor and Product	Honeywell Building Management System EBI
Remote Monitoring/Control	Yes
Data Trending	EMCS Trends, Electrical meter

Office Building B

Site

Building Type	Commercial
Utility Service Classification	SC. 9 Large - General
Location	New York, NY
Gross Floor Area	1.7 Million ft^2
No. of Buildings, Floor	1 building, 47 floors
Building Program	Office/Retail
Occupancy Schedule	Mon-Fri, 7am - 12am, Sat 9am - 6pm, Sun 11am - 6pm
Facility Management Type	Company-owned

Utility & Demand Response Programs

Energy Provider	Direct Energy - Electricity, Con Edison - Steam
Peak Load (kW)	3,940
Peak Load Intensity (W/m^2)	25
Load Factor	-
Annual Consumption (kWh)	8,716,800
Demand Response Program	NYISO SCR & EDRP, ConEd DLRP & CSRP
Curtailment Service Provider	iES

HVAC System

Air Distribution Type	Induction VAV with reheat system
Air Handler Unit	VSD
Cooling Plant	(1) 2,300-ton chiller, (1) 2,100-ton chiller, (1) 1,600-ton chiller
DDC Zone Control	Yes
Global Temperature Adjustment	No
Other System	Cogeneration plant utilizing steam to generate both electricity and boil water for the building

Lighting System

Zone Control	Multi-zone control
Centralized Control	No

Energy Management and Control System

EMCS Vendor and Product	Andover
Remote Monitoring/Control	Yes
Data Trending	EMCS Trends, Electrical meter

Office Building C

Site

Building Type	Commercial
Utility Service Classification	SC. 9 Large - General
Address	New York, NY
Gross Floor Area	1.4 Million ft^2
No. of Buildings, floor	Tower A - 40 floors, Tower D - 35 floors
Building Program	Office
Occupancy schedule	Mon - Fri, 8am - 6pm
Facility Management Type	Company-owned

Utility & Demand Response Programs - Tower A

Energy Provider	NYPA – Electricity
Peak Load (kW)	4,640
Peak Load Intensity (W/m^2)	36
Load Factor	-
Annual Consumption (kWh)	24,782,400
Demand Response Program	NYISO SCR, Con Ed DLRP
Curtailment Service Provider	Constellation

HVAC System - Tower A

Air Distribution Type	fan-powered VAV with reheat system
Air Handler Unit	VSD
Cooling Plant	(1) a 400-ton chiller
DDC Zone Control	Yes
Global Temperature Adjustment	No
Other System	

Lighting System - Tower A

Zone Control	-
Centralized Control	No

Energy Management and Control System - Tower A

EMCS Vendor and Product	Johnson Control - Legacy
Remote Monitoring/Control	Yes
Data Trending	EMCS Trends, Electrical meter

Campus Building

Site

Building Type	Campus
Utility Service Classification	SC. 9 Large - General
Address	New York, NY
Gross Floor Area	122,000 ft^2
No. of Buildings, floor	1 building, 14 floors
Building Program	Academic Institution - classroom and office
Occupancy schedule	Mon-Sun, 7am - 11pm
Facility Management Type	-
Other details	The building recently went through a complete renovation and system upgrades and was recently occupied in September 2011.

Utility & Demand Response Programs

Energy Provider	NYPA - Electricity
Peak Load (kW)	605
Peak Load Intensity (W/m^2)	53
Load Factor	0.40
Annual Consumption (kWh)	2,149,722
Demand Response Program	NYISO SCR & EDRP
Curtailment Service Provider	Comverge

HVAC System

Air Distribution Type	VAV with reheat system
Air Handler Unit	VSD
Cooling Plant	(1) a 400-ton chiller
DDC Zone Control	Yes
Global Temperature Adjustment	Yes
Other System	-

Lighting System

Zone Control	Single zone control
Centralized Control	Yes

Energy Management and Control System

EMCS Vendor and Product	Automated Logic Control
Remote Monitoring/Control	Yes
Data Trending	EMCS Trends, Electrical meter